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# C O N T E N T

# ASSESSMENT OF DIGITAL AGRICULTURAL PRACTICES AMONG COMMERCIAL ARABLE CROP FARMERS IN SOUTHWEST, NIGERIA

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***Abstract***

*Smart agriculture has the potential for economic benefits through increased agricultural productivity, cost efficiency and market opportunities through increased communication; and environmental benefits as this will in turn, lead to greater food security, profitability and sustainability. This article presents the practices and challenges to smart agriculture among commercial arable crop farmers in Southwest, Nigeria considering the forms of digitalization in use, as well as the frequency of usage, period of usage, and challenges to the usage. We randomly sampled 45 commercial arable crop farmers across the southwest states in Nigeria. We made use of Structured questionnaire to extract needed information from the respondents. The data obtained were analysed with descriptive statistics. Our findings showed that the forms of digitalization used by agricultural firms include mobile phone (100%), cloud computing (56%), software (58%), remote sensing (40%), digital marketing (52%), and GIS (35%) while the average period of usage of digitalization was 10years. Our findings also revealed that the main challenges to the use of digitalization are high cost of procurement and installation (93%), low awareness of current state of digitalization in agriculture (84%), limited technical knowhow (78%), poor power supply (67%), and high cost of energy (62%). Although evidence at short-term revealed that smart agriculture has the potential of tackling key development issues such as food insecurity, poor output, poverty, and unemployment; the study showed that there is a need to enlighten agricultural firms of the benefits of smart agriculture, as well as plan and invest on sustainability of digitalization in agriculture to harness its full benefits/potentials.*

***Key words***: *digitalization, practices, agricultural production growth, food security, sustainability*

## INTRODUCTION

Agriculture is a crucial tool for promoting growth and sustainable development, eradicating poverty, and improving the food security of the thronging populace in most emerging countries (Trading Economics, 2018) [8]. Base on the findings of Food and Agriculture Organization of the United Nations FAO (2016), Sub-Saharan Africa population could double by 2050, increasing annual agricultural consumption by 2.8% until 2030, and by 2.0% from 2030 to 2050. This rapid population growth and urbanization imply that food production will grow more slowly than demand resulting to food scarcity and increased malnutrition. Therefore, sustaining food security of this teeming population in the face of the changing climate and urbanization is a major challenge (Van Etten et al., 2019) [10]. In order to overcome these challenges and ultimately attain food security. There is need for technological adoption to incentivize large scale farming in urban areas, facilitate access to irrigation systems, improving digital farming practices and infrastructure; and implement favorable policies to support digitalization of agriculture for transformative adaptation to climate change in farming (OECD-FAO, 2016) [4].

Digitalization could help farmers to optimize their costs and achieve a greater profitability, to increase production and profitability and farmers' living standard [7].

Digital innovation in agriculture has a great opportunity to eradicate poverty and hunger.

It can also mitigate the effects of climate change. Through digitalization, all parts of the agri-food production chain will be modified, since connectivity and the processing of massive amounts of data quickly allows for more efficient work, greater economic return, greater environmental benefits, and better working conditions in the field, this development appears to hold great promise for advancing farm productivity and profitability in this primary sector (USAID, 2018) [9].

Although digital agriculture also referred to as smart agriculture is being implemented in advance world like North America, and Asia but empirical evidence on the extent of it usage in developing countries like Nigeria is thin.

Nigerian agriculture needs digitalization for better outcomes as affirmed Ferkun (2015), [1], Okafor, 2022 [5].

The National Information Technology Development Agency with the help of Nigeria's Federal Ministry of Communications and Digital Economy has launched the National Adopted Village for Smart Agriculture Program which will help 130 farmers to build digital skills and innovations across agriculture value chains and this will create new jobs, increase agricultural production, income and wealth of every ecosystem player (Opali, 2020) [6].

Photo 1. Femi Adekoya - The Nigerian farmer transforming agriculture with drone technology
Source: Ventures Africa (2022) [11].

Nigeria Digital Agriculture Strategy 2020-2030 has the goal to adopt digital technologies in agriculture. A digital platform will be put at the disposal of the beneficiaries in order to enable them to communicate, exchange ideas, efficient practices, find jobs, markets for products delivery, to develop agri-business (Nigeria Digital Agriculture Strategy 2020-2030) [3].

Therefore, this study aimed to fill the gap by assessing digital agricultural practices among commercial arable crop farmers in Southwest, Nigeria.

The specific objectives are to:

(i)describe the socio-economic characteristics of the respondents;

(ii)consider the forms of digitalization in use among commercial arable crop farmers;

(iii)examine the frequency of usage and period of usage of digitalization and;

(iv)highlight the challenges to the usage of digitalization.

## MATERIALS AND METHODS

### Study Area, Source of Data and Sampling Procedure

The study was conducted in Southwestern states, Nigeria. Primary data used for the study was obtained through structured questionnaire. The population for the study comprised all commercial arable crop farmers. A three-stage sampling technique was used. The first stage involved choosing at random three of the six states in the area; the second stage involved choosing at random three ecological zones in each state; while the third stage involved random selection of five commercial arable crop farmers in each zones. In all, a total of forty-five (45) commercial arable crop farmers were used for the study.

### Analytical Tools

The tool of analysis that was used was descriptive statistics which include mean, median, frequency and percentages.

## RESULTS AND DISCUSSIONS

### Socio-economic Characteristics of Farmers

Table 1 revealed that 68.7% of the respondents are younger than 44 years old. This shows that the majority of those who own and manages agricultural firms are still in their middle years and employ some sort of digitalization in their business. Younger farmers typically absorb innovations more quickly than elderly farmers since the latter tend to stick to their traditional methods of production and are frequently resistant to change.

The data also showed that men made up 75.6% of the respondents while women made up 24.4%. This demonstrates that men are more prevalent in agriculture. The majority of respondents had tertiary education, which made it simple for them to incorporate digital skills into their production activities (Kamilu and Oyeyinka, 2011) [2].

tertiary education, which made it easy to adopt digital skills in their production activities.

Voh (2002) [12] reported that there is a positive and significant relationship between formal education and adoption of technologies.

Table 1. Socio-economic Characteristics of Respondents

| Characteristics | Frequency | Percentage (%) |
|---|---|---|
| **Age (Years)** | | |
| ≤30 | 2 | 4.4 |
| 31 – 40 | 25 | 55.6 |
| 41 – 50 | 13 | 28.9 |
| 51 – 60 | 5 | 11.1 |
| **Sex** | | |
| Male | 34 | 75.6 |
| Female | 11 | 24.4 |
| **Education level** | | |
| Secondary education | 2 | 4.4 |
| Tertiary education | 43 | 95.6 |
| **Marital status** | | |
| Single | 4 | 8.8 |
| Married | 36 | 80.0 |
| Divorced | 3 | 6.7 |
| Widowed | 2 | 4.5 |
| **Total** | **45** | **100.0** |

Source: Field survey, 2020.

The result further revealed that about 80.0%, 8.8%, 6.7% and 4.5% of the farmers are married, single, divorced and widowed respectively. This indicates that most of the people involved in agricultural activities in the area are married.

**Forms of digitalization adopted in farms**

All the agricultural firms under study use mobile telephone to deliver services to farmers throughout Nigeria. They equally partner with GSM operators for special tariffs to enable them carry out their agricultural production and Consultancy Services efficiently.

Fifty-six percent (56%) of the agricultural firms provide their products and services to farmers through the cloud. This helps them to instantly store and analyze farmers' fields and crop data efficiently by keeping all their systems on the cloud. It ensures that services can be offered over all devices that can be connected to the Internet irrespective of the location.

Fifty-eight percent (58%) of the firms employ software like Matlab, Sas and E-views for their big data analysis for efficient delivery of services. Twelve percent (12%) of the agricultural firms can interpret and make use of measurements made from meteorological stations for their planting activities. Such climatic information includes information on rainfall, temperature, relative humidity etc.

Eight percent (8%) use drones for their herbicide and pesticide application. Twenty five (25%) also make use of soil sensing device for their planting activities.

While none of the agricultural firms under study uses robotic machines for their agricultural enterprise (Figure 1).

**Frequency of Usage Digitalization**

Table 2 presents the frequency of usage of digitalization by the firms under study. Mobile Phone, GIS and Digital Marketing were used very frequently by the firms; Software and Cloud Computing were used frequently; Drones, Remote sensing and Soil Sensing were used occasionally; while Robotic machines are not used by any of the firms.

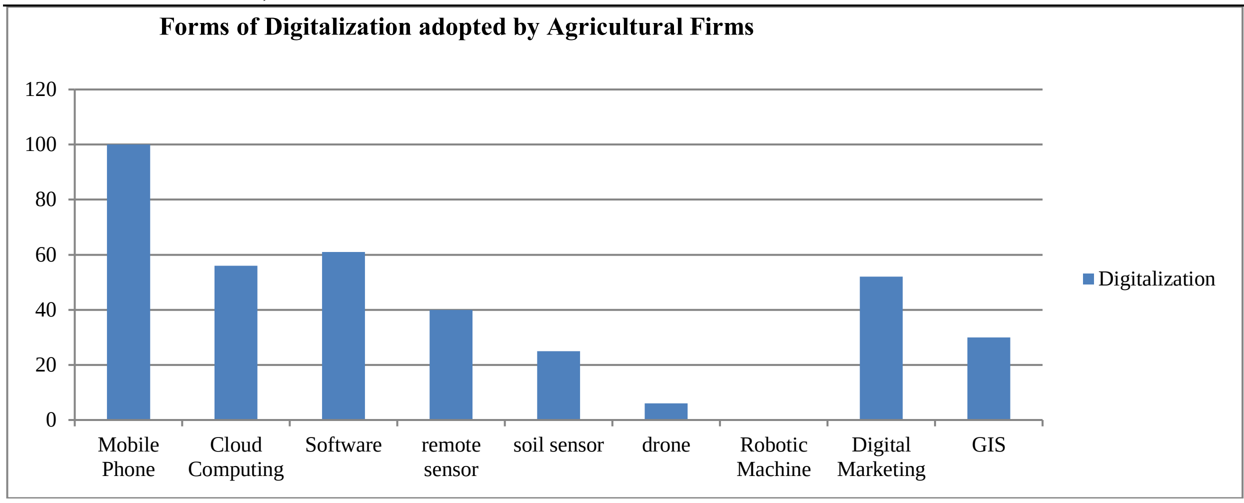


Fig. 1. Forms of Digitalization used by Agricultural Firms
Source: Field survey, 2020.

Table 2. Frequency of usage digitalization (n = 45)

| S/N | List of ICTs | VF (%) | F (%) | O (%) | R (%) |
|---|---|---|---|---|---|
| 1 | Drones | 14.0 | 15.2 | 45.8 | 25.0 |
| 2 | Software | 23.4 | 62.5 | 9.0 | 5.1 |
| 3 | Mobile phone | 85.0 | 12.3 | 2.7 | 0.0 |
| 4 | Remote sensing | 4.5 | 10.5 | 52.8 | 32.2 |
| 5 | GIS | 72.6 | 11.4 | 10.0 | 6.0 |
| 6 | Digital Marketing | 65.8 | 23.5 | 7.5 | 3.2 |
| 7 | Cloud computing | 12.2 | 58.6 | 15.2 | 14.0 |
| 8 | Soil sensor | 10.0 | 25.8 | 56.0 | 8.2 |
| 9 | Robotic machine | 0.0 | 0.0 | 0.0 | 0.0 |

N.B: Very Frequently (VF), Frequently (F), Occasionally (O), Rarely (R)
Source: Field survey, 2020.

## Period of Usage

Table 3 shows the period of usage of digitalization by the agricultural firms. The modal period of usage by the agricultural firms is between 5-10years while the average period of usage is 10.15years which shows the use of digitalization is still in it early stage.

Table 3. Period of Usage of Digitalization

| Years | Frequency | Percentage |
|---|---|---|
| < 5 | 03 | 4.4 |
| 5-10 | 21 | 46.7 |
| 10-15 | 19 | 42.2 |
| >15 | 03 | 6.7 |
| Total | 45 | 100.0 |

Source: Field survey, 2020.

## Challenges to Digital Agriculture in Nigeria

Table 4 shows the constraints facing digital agriculture in Nigeria. The constraints include: High Cost of procurement and installation, Low awareness of current state of digitalization in agriculture, Limited Technical Knowhow, Poor Power Supply, High Cost of Energy, Inaccessibility to small scale farmers and Fear of operational risk associated with digital agriculture.

Table 4. Challenges to digital agriculture in Nigeria

| Challenges | Freq. | % |
|---|---|---|
| Limited Technical Knowhow | 35 | 77.8 |
| Poor Power Supply | 30 | 66.7 |
| High Cost of procurement and installation | 42 | 93.3 |
| Inaccessibility to small scale farmers | 25 | 55.6 |
| Low awareness of current state of digitalization in agriculture | 38 | 84.4 |
| Fear of operational risk associated with digital agriculture | 21 | 46.7 |
| High cost of energy (fuel) | 28 | 62.2 |
| N- Multiresponse | | |

Source: Field survey, 2020.

## CONCLUSIONS

The study concludes that smart agriculture has the potential of tackling key development issues such as food insecurity, poor output, poverty, and unemployment. The study that there is a need to enlighten agricultural firms of the benefits of smart agriculture and adequate infrastructures should be put in place to tackle the challenges to the usage of digital agriculture.

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# SOCIO-ECONOMIC FACTORS INFLUENCING LIVELIHOOD DIVERSIFICATION AMONG RURAL FARMING HOUSEHOLDS IN SOUTHWEST NIGERIA: A FRACTIONAL RESPONSE MODEL APPROACH

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***Abstract***

*The socioeconomic factors influencing livelihood diversification among rural farming households was explored in this study. To choose 300 respondents for the study, a multistage sampling technique was used. A well-structured questionnaire was used to collect data on rural farming household's socio-economic characteristics, livelihood activities engaged in by farming households. Descriptive statistics, Simpson Index of Diversification and Fractional response model were used to examine the data. The result revealed that rural farming households were majorly headed by males who were in their late middle ages, with large household size. The study also revealed that sex of the household heads, marital status, household size, educational level, farm size, farming experience and amount of credit obtained were significant socio-economic factors influencing livelihood diversification among rural farming households. The study recommends that increased efforts should be made to make credit accessible to rural farming households. This will encourage diversification into various livelihood activities, leading to increased productivity and income.*

***Key words***: *livelihood diversification, rural farming households, Fractional Response model*

## INTRODUCTION

Innovation in rural areas involves both livelihood diversification of the households [12] and also the implementation of a new concept regarding the development of the local communities [14]. Rural farming household's main source of livelihood is farming, which is subsistent in nature. They cultivate on small expanse of farm land of less than two-hectares in size [3, 6, 10]. Their farming activities provide for the household food and other basic needs while the meager marketable surpluses are traded to earn income [18]. Rural farming households gets their income from farm income which is equated as agricultural income and is not sufficient to meet their basic needs. Rural farming households do not get optimum economic returns on their produce due to various factors ranging from inadequate storage facilities, lack of good processing techniques, poor road networks [9]. In order to reduce their dependence on farming activities alone, rural farming households are beginning to diversify their means of livelihood. Livelihood diversification helps rural households to make use of their idle labour hours particularly in the slack period of farming activities [1]. The income generated through such activities are then used for family sustenance in the case of economic challenges or invested in farm enterprises among rural farming households [5]. Livelihood diversification which encompasses economic activities associated with different crop production, livestock husbandry, off-farm and non-farm enterprises have been seen as sources of succor by rural farming households. They range from planting different varieties of crops, raising of animals, diversifying from low-value crops to high value crops and engagement in artisanal to other off-farm activities [17, 21]. Income from livelihood diversification is important to the rural poor as farm income obtained by poorer households is not enough to meet family needs. Since smallholder farming activities are seasonal in nature, farming households take livelihood diversification as income supplements as well as critical source of liquidity for those who are credit constrained. It also provides resources needed for investment in advanced agricultural technologies that could lead to increased agricultural productivity [4]. Livelihood diversification also helps rural farming households to absorb farm income shocks and improve income distribution [24]. Several studies [16, 22, 25] on livelihood diversification have been conducted among rural farming households, and has shown that rural farming household diversify. Although, literature on socio-economic factors influencing livelihood diversification among rural farming households in Southwest, Nigeria are still scanty. Also, the participations of rural farming households in various livelihood activities as well as the contribution of off-farm livelihood activities to total household is still small compared to farm income. There is a need to identify the socio-economic factors influencing livelihood diversification. Consequently, the study investigated the socio-economic factors influencing livelihood diversification among rural farming households in the study area. Specifically, the study describes the socioeconomic characteristics of rural farming households in the study area; identifies the livelihood sources among rural farming households in the study area; determines the level of diversification among rural farming households in the study area; and determines the socio-economic factors affecting livelihood diversification among rural farming households in the study area.

## MATERIALS AND METHODS

### Study Area

The study was carried out in Southwest, Nigeria, which comprises of six states (Ekiti, Lagos, Osun, Oyo, Ondo and Ogun). The study area in the North, shares boundaries with Kogi and Kwara States, to the East with Edo and Delta States, in the Western side by the Republic of Benin and to the South by the Gulf of Guinea. The zone has a total land area of 77,818 km$^2$ and an estimated population of 38,257,260 [15]. The climate of southwest Nigeria is tropical in nature and is characterized by wet and dry seasons. The temperature ranges between 21$^o$C and 34$^o$C while the annual rainfall ranges between 1,500mm and 3,000mm. The climatic condition encourages the cultivation of early and/or late crops such as cassava, yam, millet, rice, plantains, cocoa, palm produce, cashew and maize. The major occupation of people in this geopolitical zone include farming, trading, hair dressing, carpentry, marketing as well as food processing [17].

### Sampling Procedure and Sample size

Multistage sampling technique was employed for this study. The first stage involved random selection of two States Oyo and Ondo out of the six states in the southwest region of Nigeria. Based on proportionate sampling, four and two Local Government Areas (LGAs) were randomly selected from Oyo and Ondo States respectively. From each of the resulting six LGAs, five villages were further randomly selected at the third stage, giving a total of thirty villages. The last stage involved a random selection of ten farming households from each village. In all a total of three hundred farming household were selected for the study. The sample size was a proportion of the population at 5% level of significance and 6% margin of error following Cochran method of sample determination.

### Method of Data Collection

Primary data were employed for this study. Data were collected with the aid of well-structured questionnaire. Data were collected on rural farming household's socio-economic characteristics such as age, years of experience, educational status, household size, marital status, farm size of the household heads, membership of cooperative societies, access to credit. Data were collected on the number of livelihood activities engaged in by farming households.

**Analytical techniques**

Descriptive statistics simpson index of diversification, fractional response model were used to analyse the data collected.

**Descriptive Statistics**

Descriptive statistics such as frequency tables, percentages and means were used to describe the socio-economic characteristics of rural farming households and identify different livelihood sources that exist in the study area.

**Simpson Index of Diversification**

The level of livelihood diversification was determined using Simpson index of diversification. Simpson index of diversification was used because of its computational simplicity, robustness and wider applicability. It is specified as:

$$SID=1-\sum_{i=1}^{n} Pi^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where:
SID= Simpson index (measure of livelihood diversification)
n =total number of income sources
Pi= income proportion of ith income source.

Pi is specified as:

$$Pi=\left(\frac{mi}{mt}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where:
$m_i$ = income from each activity
$m_t$ = household's total income from all activities.

Based on the values of SID, level of livelihood diversification was specified as:

1. No diversification (SID < = 0.01)
2. Diversification level is low, when (SID = 0.01 - 0.25)
3. Diversification is at medium level, when (SID = 0.26 - 0.50)
4. Diversification is at high level, when (SID = 0.51 - 0.75)
5. Diversification level is very high, when (SID > 0.75)

**Fractional response model**

A fractional response model was employed to evaluate socio-economic factors influencing livelihood diversification (objective 4) in the study area. This in line with [11] In the model, livelihood diversification index is the dependent variable. Fractional response model is more suitable because the level of livelihood diversification is a fraction variable bounded between 0 and 1. And the fractional variables are not censored.

The fractional response model is defined as:

$$E(Y/X)=G(X\beta) \quad \ldots\ldots\ldots(3)$$

The model is implicitly defined as:

$$E(SID/X)=Xb+\varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

where:
SID = the dependent variable as defined above,
X= matrix of independent variables
*b* = vector of parameters to be estimated
e = error term.

Fractional response model is used to estimate the *b* vector of the model because the dependent variable is a fraction which is confined to zero and one.

The model was explicitly specified as:

$$E(SID/X) =E (Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + e\ldots\ldots\ldots\ldots \quad (5)$$

Thus, the explanatory variables used in the analysis are:
Y* = livelihood diversification index [as derived from (4)]
$X_1$= age (Years)
$X_2$= sex (Male = 1, Female =0)
$X_3$= marital status (1=Married, 0=otherwise)
$X_4$= level of education (years)
$X_5$= household size (number of persons)
$X_6$ = Farming experience (years)
$X_7$= membership of association (expressed as a dummy; if yes1, if otherwise 0)
$X_8$= farm size (hectares)
$X_9$= extension visits (number)
$X_{10}$ = credit (amount in naira)
e=Random error

## RESULTS AND DISCUSSIONS

**Socioeconomic Characteristics of the rural households**

Table 1 shows that majority (85.0%) of the rural household were headed by males while

15.0% were headed by females. This could be because farming activities in rural areas are mostly carried out by males who mostly have title to land and are the breadwinners of most homes, while the female counterpart were involved in processing and marketing of agricultural products. This enhances diversification of livelihood in the rural setting to cater for the welfare of the household. The age distribution of the respondents revealed that majority of the farmers (42.0%) were aged between 41-50 years with a mean age 51.3±8.14 years. This implies that majority of the household heads were in their late middle ages but still productive to engage in agricultural production and explore various livelihood opportunities. The finding is in agreement with that of [2] who stated that participants in farming activities were energetic and economically active to engage in farming and other livelihood activities. The result further revealed that majority (87.0%) of the respondents were married, 63.3% of the respondents had a household size that ranged from 5-8 members, with an average household size of 7.16±2.34 members. From the result, the household size is fairly large suggesting that there may be availability of family labour for their occupations, but will incure high family expenses hence households with large members need to depend more on various income generating activities to meet family needs. This confirms the view that large family size has better chance of livelihood diversification than households with small size [8, 23].

The level of education among the respondents was fairly low as nearly 63.4% of the respondents had less than secondary education, 9.0% completed tertiary education while 27.7% had no formal education. The low level of education among rural farming households head, might have serious implications on their earning capacity as they may lack skills to secure well-paid jobs, thereby affecting the poverty status of the respondents. This assertion is in line with the findings of [23], who stated that low literacy level among farming households will make it difficult for farming households to adopt modern improved techniques on how to increase their income.

While Majority of the respondents (82.7%) engaged in farming as their primary occupation, the remaining 17.3% were into farming as secondary occupation as they engaged in other livelihood activities like artisans, trading, civil service. This shows that farming is the predominant source of income among rural households. This is in line with the findings of [20] who posited that farming is the main occupation among farming households in rural areas. The result revealed that 75.7% had between one and five hectares of farm land while 16.8% of the households had more than six hectares of farm land. The mean farm size owned was 3.29±2.99. Although the mean farm size is small. This shows that rural farming households practice farming on a small scale, which affect their income, thereby leading to households diversifying into other sources of income to cater for family needs. From the result, about 59.7% of the respondents were members of farmer’s associations or cooperative societies while 40.3% of the respondents were not. The result showed that more than two-third (79.0%) of the respondents had no access to credit, while only 21.0% had access to credit. This implies that there was limited access to credit among the respondents which may reduce the opportunities of diversifying into various livelihood opportunities. The result also revealed that majority (32.3%) of the respondents have never been visited by any extension agent while 32.0 % of the respondents were visited twice. Thus, rural farming households would have limited relevant information on farm business to increase their output and hence their income. This confirms the view that majority of the households had no access to innovations that would increase their agricultural output in order to increase their income [23]. The result also showed that majority (31.3%) of the household earned between ₦500,000-₦749,999 while 24.3% of the households earned income between ₦250,000 - ₦499,999. The mean household annual income of the respondents was ₦58,0145±₦40,1142.1.

Table 1. Socio-economic characteristics of respondents

| Characteristics | Frequency | Percentage |
|---|---|---|
| **Gender** | | |
| Male | 255 | 85.0 |
| Female | 45 | 15.0 |
| Total | 300 | 100.0 |
| **Age (Years)** | | |
| ≤30.0 | 3 | 1.0 |
| 31-40.0 | 34 | 11.3 |
| 41-50.0 | 126 | 42.0 |
| 51-60.0 | 106 | 35.3 |
| 61.70.0 | 27 | 9.0 |
| >70.0 | 4 | 1.3 |
| Total | 300 | 100.0 |
| **Marital status** | | |
| Single | | |
| Married | 4 | 6.7 |
| Divorced | 261 | 87.8 |
| Widowed | 15 | 1.1 |
| Total | 20 | 2.8 |
| | 300 | 100 |
| **Level of education (years)** | | |
| No formal education | 83 | 27.7 |
| Adult education | 2 | 0.7 |
| Primary school | 97 | 32.3 |
| Secondary school | 91 | 30.3 |
| Tertiary school | 27 | 9 |
| Total | 300 | 100 |
| **Main occupation** | | |
| Farming | 248 | 82 |
| Trading | 22 | 8.0 |
| Artisan | 18 | 6.0 |
| Civil servant | 12 | 4.0 |
| Total | 300 | 100 |
| **Household size** | | |
| 1-4 | 28 | 9.3 |
| 5-8 | 134 | 44.7 |
| 9-12 | 121 | 40.3 |
| ≥13 | 17 | 5.7 |
| Total | 300 | 100.0 |
| **Farm size (Hectares)** | | |
| ≤ 1.0 | 22 | 7.30 |
| 1.1-5.0 | 227 | 75.7 |
| 5.1-10.0 | 46 | 15.3 |
| >10.0 | 5 | 1.70 |
| Total | 300 | 100 |
| **Membership of cooperative/ association** | | |
| Yes | 179 | 59.7 |
| No | 121 | 40.3 |
| Total | 300 | 100 |
| **Access to formal Credit** | | |
| Yes | 63 | 21.0 |
| No | 237 | 79.0 |
| Total | 300 | 100 |
| **Number of Extension agents visit within a year** | | |
| No visitation | 106 | 35.3 |
| Once | 17 | 5.7 |
| Twice | 96 | 32.0 |
| More than twice | 81 | 27.0 |
| Total | 300 | 100 |
| **Household Annual Income (₦)** | | |
| <₦250,000 | 54 | 18.0 |
| ₦250,000 - ₦499,999 | 73 | 24.4 |
| ₦500,000 - ₦749,999 | 94 | 31.3 |
| ₦750,000 - ₦999,999 | 64 | 21.3 |
| ≥₦1,000,000 | 15 | 5.0 |
| Total | 300 | 100 |

Source: Field Survey, 2021.

**Livelihood sources among rural farming households in the study area**

Livelihood sources available among rural farming households is presented in Table 2. The table shows household participation in different livelihood sources as well as the share of income from these sources. Household participation in different livelihood activities was calculated by dividing the number of respondents that engaged in a particular livelihood activity by the total number of respondents and then multiply by 100. The income share among rural farming household was calculated, by dividing the total income generated from all the respondents that participated in a particular livelihood activity by the total income of all the sampled respondents, and then multiply by 100. The result showed that all the farming households (100%) derived income from farming activities which accounted for 26.0% of the total income. Other livelihood activities identified among rural farming households in the study area are agricultural labour, hunting, grinding, food vending, food processing, trading, artisans (Tailors, hairdressers, welders, mechanics, carpenters, electricians, bricklayers), civil servant, private workers and transportation business. 35.0% of the respondent participated in trading with total income share of 6.9%, 27.7% of the respondent participated in artisanship with total income share of 5.9%, 6.3% of the respondents engaged in transportation as a means of livelihood with a total income share of 9.0%, 5.0% of the respondents were civil servant with a total income share of 15.6%, while about 1.3% of the respondents engaged in the processing of agricultural produce with a total income share of 3.6%.

Table 2. Livelihood sources among rural farming households

| **Livelihood activities** | **Frequency** | **Participation (%)** | **Share of income (%)** |
|---|---|---|---|
| Farming | 300 | 100 | 26.0 |
| Agricultural Labour (wage) | 10 | 3.3 | 5.5 |
| Hunting | 9 | 3.0 | 6.1 |
| Trading | 107 | 35.7 | 6.9 |
| Grinding | 6 | 2.0 | 5.3 |
| Food Vending | 11 | 3.7 | 6.8 |
| Agricultural Processing | 4 | 1.3 | 3.6 |
| Artisan | 83 | 27.7 | 5.9 |
| Civil servant | 15 | 5.0 | 15.6 |
| Private workers | 5 | 1.7 | 9.3 |
| Transportation business | 19 | 6.3 | 9.0 |
| **Total** | 569 | 189.7 | 100 |

Source: Field Survey, 2021.
*Multiple response due to multiple jobs by some of the respondents

This implies that aside farming, majority of the farming households engage in off-farm and non-farm activities to increase their earnings. This is in line with the findings of [23] who found out that farming households engage in farming and other non-farming activities such as agricultural trading, forest production, agricultural processing, artisans, construction works and transportation business.

**Level of livelihood diversification**

Table 3 shows the level of diversification among rural farming household, livelihood diversification was determined using Simpson Index of Diversification (SID). The result revealed that 10.3% of the households did not diversify, 8.0% of the households have poor diversification level while 50.0% of the households diversified at a medium level of diversification. Although on the contrary 31.7% of them diversified their income sources at a high level. Consequently, the overall mean value of Simpson diversification is 0.4, which indicates a medium level of diversification across all farming households in the study area.

Table 3. Distribution of household per level of livelihood diversification

| **Simpson index range** | **Frequency** | **(%)** | **Level of diversification** |
|---|---|---|---|
| <= 0.01 | 31 | 10.3 | No Diversification |
| 0.02-0.25 | 24 | 8.0 | Low |
| 0.26-0.50 | 150 | 50.0 | Medium |
| 0.51-0.75 | 95 | 31.7 | High |
| Total | 300 | 100.0 | |
| Mean | 0.41 | | |
| Stand. Deviation | 0.19 | | |
| Minimum | 0.00 | | |
| Maximum | 0.75 | | |

Source: Field survey, 2021.

**Socio-economic factors influencing livelihood diversification among rural farming households**

Fractional response model was used to determine the socioeconomic factors influencing livelihood diversification as presented in Table 4. Firstly, in the estimated model, the variance inflation factor (VIF) of the variables were computed to check the presence or absence of multicollinearity. The result indicated that none of the variables had a VIF value up to 10. The general thumb rule state that the VIFs exceeding 10 are signs of serious multicollinearity which require corrections. The mean VIF values of all explanatory variables was 2.27 which is less than 10, indicating that multicollinearity was not a problem. The socioeconomic factors influencing livelihood diversification of respondents is shown by the results of the Fractional response model as presented in Table 3. The value of wald chi-square which was statistically significant at 10% with log pseudo-likelihood of -202.1181 confirmed the goodness of fit of the model. The result shows that seven of the explanatory variables, age of respondents ($X_1$), sex of respondents ($X_2$), household size ($X_5$), farming experience ($X_6$), membership of association ($X_7$), farm size ($X_8$) and extension visit ($X_9$) were positively related to level of diversification. The other three variables: marital status ($X_3$), educational level ($X_4$) and amount of credit ($X_{10}$) were negatively related to level of diversification. The result shows that five out of the ten explanatory variables were statistically significant at acceptable levels. In other words, sex of the household heads ($X_1$), education of the household heads ($X_4$), household size ($X_5$), farm size ($X_8$), and credit amount ($X_{10}$) were the significant socio-economic factors which influenced livelihood diversification among rural farming households in the study area.

The coefficient of the sex of household head was positive and significantly influenced livelihood diversification at 10% probability level. As shown, a unit increase in male headed households increases the chance of livelihood diversification by 5.33%. This is in conformity with *a priori* expectation, because male headed households are the breadwinners of most homes and have more responsibilities to fulfil than their female counterpart which influences livelihood diversification. This is in line with the findings of [21] indicating that male headed households engage in more income generating activities than their female counterpart. The coefficient of household size was positive and significant at 5%. As shown, a unit increase in the member of a household would increase the level of livelihood diversification by 1.03%. This is in line with *a priori* expectation because households with large household sizes will be influenced to access various income earning opportunities to meet household needs and thereby reduce household poverty. The result agrees with the findings of [13] who reported that household size had a positive impact on livelihood diversification because the availability of more labour power among farming household members encouraged them to participate in various livelihood activities.

Table 4. Fractional response model of Socio-economic factors influencing livelihood diversification

| **Variables** | **Coefficient** | **P-value** | **Marginal effects** | **VIF** |
|---|---|---|---|---|
| Age | 0.0039 (0.0048) | 0.409 | 0.0015 | 2.33 |
| Sex | 0.1369 (0.09) | 0.146* | 0.0533 | 2.22 |
| Marital status | -0.0851 (0.07) | 0.206 | 0.0301 | 2.29 |
| Education | -0.0101 (0.0056) | 0.071* | -0.0039 | 1.19 |
| Household size | 0.0266 (0.013) | 0.036** | 0.0103 | 1.29 |
| Farming experience | 0.0066 | 0.331 | 0.00254 | 2.40 |
| Membership of an association | 0.0591 (0.0062) | 0.347 | 0.0226 | 1.15 |
| Farm size | 0.0831 (0.04) | 0.025** | 0.0151 | 4.28 |
| Extension visit | 0.0027 (0.02) | 0.868 | 0.0062 | 1.22 |
| Credit amount | -5.99e-07 (3.25e-07) | 0.065** | 1.31e -07 | 4.35 |
| Constant | -0.5129 (0.23) | 0.026** | 0.0301 | 2.27 |
| /sigma | 282.3231 | | | |
| Number of observation | 300 | | | |
| Log pseudo-likelihood | -202.1181 | | | |
| Wald chi (10) | 16.90 | | | |
| Prob> chi 2 | 0.0765 | | | |

Source: Data Analysis, 2021.
** Significant at 5% *Significant at 10%
* Standard error in parenthesis ()

Also, the coefficient of farm size was positively significant at 5%. The result implies that, a unit increase in the number of hectares of farm land cultivated by farming households would increase the level of livelihood diversification by 1.51%. This could be because they can either process the resulting increase in farm products or they will earn higher income, which they can subsequently invest in other enterprises. On the other hand, coefficient of years of formal education of the household head had negative sign and was statistically significant at 10%. The result of the marginal analysis implies that a unit increase in the number of years of formal education of household heads would decrease the need to diversify into other livelihood activities by 0.39%. The probable reason is that education provides necessary skills and abilities to get a permanent job which leaves them with less idle time and then leads an individual to get income from one source. The result is in conformity with the findings of [7], that educated persons get income from a single source. Also, amount of credit received by farming household was found to be statistically significant at 5% and negatively influence livelihood diversification. As shown, a unit increase in the amount of credit received by farming households decreases the level of livelihood diversification by 1.31e-05. This implies that households who have access to credit are less likely to diversify into other means of livelihood activities. Probable reason for this is that amount of credit obtained might be too little to diversify to other livelihood activities, however, this is contrary to *a priori* expectation. The result is also contrary to [7] which found out that the amount of credit obtained significantly and positively influenced livelihood diversification because credit helps the household to invest in both farm and non-farm activities.

## CONCLUSIONS

The study investigated the socioeconomic factors influencing livelihood diversification. The study concluded that farming is the main livelihood activities that rural farming households engages in. Sex, household size, educational level, farm size and amount of credit obtained were significant socioeconomic factors influencing livelihood diversification among rural farming households in the study area Therefore, the study recommended that farming households should be encouraged to increase their production, by exposing them to improved farming techniques that can aid increase productivity by the extension agent, also increased efforts should be made to make credit accessible to rural farmers. This will encourage diversification into various livelihood activities, which will lead to increased productivity and income.

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# THE VARIATION OF PROTEIN CONTENT IN MAIZE GRAINS IN RELATION TO THE FERTILIZATION LEVEL

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***Abstract***

*The study analyzed the variation of protein content in maize grains under the influence of mineral fertilization. The experiment was organised at the Agricultural Research and Development Station Lovrin, Timis County, Romania. The study was carried out under the conditions of the 2019-2020 agricultural years, on a chernozem type soil with medium fertility. The corn hybrid DEKALB 4541, non-irrigated culture system, was cultivated. Fertilization was done with nitrogen (ammonium nitrate, doses between 0-200 kg $ha^{-1}$ N, active substance) and phosphorus (concentrated superphosphate, doses between 0-160 kg $ha^{-1}$ $P_2O_5$, active substances). The combination of the two fertilizers resulted in 25 fertilization variants (V0 – control, to V25). The protein content (Pro, %) recorded values between 5.5±0.62% and 9.5±0.73%. The variation of the protein content under the influence of N, on each level of P, was described by polynomial equations of the 2nd degree, under statistical safety conditions ($R^2$=0.854 to $R^2$=0.975). The regression analysis facilitated the description of the protein content variation (Pro, %) in relation to N and P as a direct action and interaction, and the generation of 3D graphic models and in the form of isoquants, under statistical safety conditions. The cluster analysis facilitated the grouping of the variants based on the Euclidean distances, in relation to the similarity for the protein content values generated, in conditions of statistical safety condition (Coph. corr. =0.872).*

***Key words*: *3D model, cluster analysis, maize, mineral fertilizers, protein content, regression analysis***

## INTRODUCTION

The consumption demand for vegetable protein resources in the human diet is high and will continue to grow in the coming decades, a number of factors being considered important in this regard [15]. Comparative analyzes highlighted the differences, advantages and benefits of the two categories of protein sources, vegetable and animal, in human nutrition [8, 28].
Studies of protein content from different sources have evaluated functional and nutritional properties for the human or animal body [33].
Maize is a cereal plant of high importance in the world, and the production of grains represents an important source of protein for human consumption, animal consumption, industrialization [13, 25, 38].
The quality of corn production, and especially in terms of protein content, depends on the cultivated genotype but also on the interaction between genotype and environmental conditions [1, 11, 19, 31].
The improvement of the protein content in corn has been addressed both through breeding programs [21, 34], and through culture technologies [2, 18].
The protein content, as an important quality index of agricultural production, has been studied in field crops in relation to productivity elements, and different quantitative and qualitative production elements and indices [16].
Maize is a plant with high ecological plasticity, and it is cultivated on extensive areas in the world and responds differently to the various pedoclimatic conditions [27, 30, 35].
Maize culture, production and quality indices were studied in relation to soil conditions [12, 26], climatic conditions [7, 20], irrigation conditions [9, 12, 24], fertilizers [5, 6, 10], stress factors [23, 36], and other influencing conditions.

The present study evaluated the influence of mineral fertilization with nitrogen (N) and phosphorus (P) on the protein content in corn grains, and found models to describing the variation of the protein content in relation to N and P, respectively calculated the optimal doses for fertilizers in relation to the protein content.

## MATERIALS AND METHODS

The study was organised within SCDA Lovrin, Timis County, Romania. The location of the experimental field was made on a chernozem type soil with medium fertility, and the maize crop was in a non-irrigated system. The 2019 – 2020 agricultural years was taken into account. By fertilizing, nitrogen and phosphorus fertilizers were applied differently. Phosphorus fertilizers (concentrated superphosphate, 47% $P_2O_5$) were applied in doses between 0 - 160 kg $P_2O_5$ $ha^{-1}$ active substance (a.s.). The phosphorus fertilizers were applied in the fall, and incorporated into the soil with the basic soil works. On each phosphorus level, nitrogen fertilizers (ammonium nitrate, 33.5% N) were applied in doses between 0 - 200 kg N $ha^{-1}$ active substance. Nitrogen was applied twice, in the spring. The combination of the two factors (N and P) resulted in 25 experimental variants, in four repetitions. The size of a plot was 36 $m^2$. The corn hybrid DEKALB 4541 was cultivated in a non-irrigated system. At physiological maturity, production samples were collected for each experimental variant and repetition. The protein content was determined by NIR photometry, PERTEN INFRAMATIC 9200 apparatus. For the analysis and interpretation of the experimental data, the standard error (SE) was calculated, and the analysis of variance, regression analysis and cluster analysis were used [14, 37].

## RESULTS AND DISCUSSIONS

Under the influence of the fertilization options, maize crop, the DEKALB 4541 hybrid, made different use of the nutritional conditions provided, and the qualitative level of grain production, in terms of protein content (Pro, %), recorded different values. Protein content values were recorded between 5.93±0.23% in the case of the V11 variant and 8.75±0.23% in the case of the V20 variant. The values of the protein content obtained under the experimental conditions are presented in Table 1, where the values for the standard error (SE) were calculated, in the case of each variant. The graphic distribution of the protein content variation in relation to the fertilization variants is shown in figure 1.

Table 1. Values of protein content in corn grains, the DEKALB 4541 hybrid, under the influence of mineral fertilization

| Experimental variants | N | P | Protein content (Pro) and Standard Error (SE) |
|---|---|---|---|
| | (kg a.s. $ha^{-1}$) | (kg a.s. $ha^{-1}$) | (%) |
| V1 | 0 | 0 | 6.18±0.22 |
| V2 | 50 | 0 | 7.30±0.63 |
| V3 | 100 | 0 | 7.55±0.46 |
| V4 | 150 | 0 | 7.98±0.29 |
| V5 | 200 | 0 | 7.98±0.27 |
| V6 | 0 | 40 | 6.15±0.15 |
| V7 | 50 | 40 | 6.93±0.60 |
| V8 | 100 | 40 | 7.28±0.27 |
| V9 | 150 | 40 | 8.03±0.31 |
| V10 | 200 | 40 | 8.05±0.30 |
| V11 | 0 | 80 | 5.93±0.23 |
| V12 | 50 | 80 | 7.48±0.49 |
| V13 | 100 | 80 | 7.58±0.14 |
| V14 | 150 | 80 | 8.50±0.29 |
| V15 | 200 | 80 | 8.03±0.22 |
| V16 | 0 | 120 | 6.18±0.19 |
| V17 | 50 | 120 | 6.33±0.16 |
| V18 | 100 | 120 | 7.73±0.14 |
| V19 | 150 | 120 | 8.28±0.21 |
| V20 | 200 | 120 | 8.75±0.23 |
| V21 | 0 | 160 | 6.23±0.24 |
| V22 | 50 | 160 | 7.68±0.73 |
| V23 | 100 | 160 | 7.48±0.46 |
| V24 | 150 | 160 | 7.98±0.33 |
| V25 | 200 | 160 | 8.30±0.25 |

Source: original data recorded from the experiment.

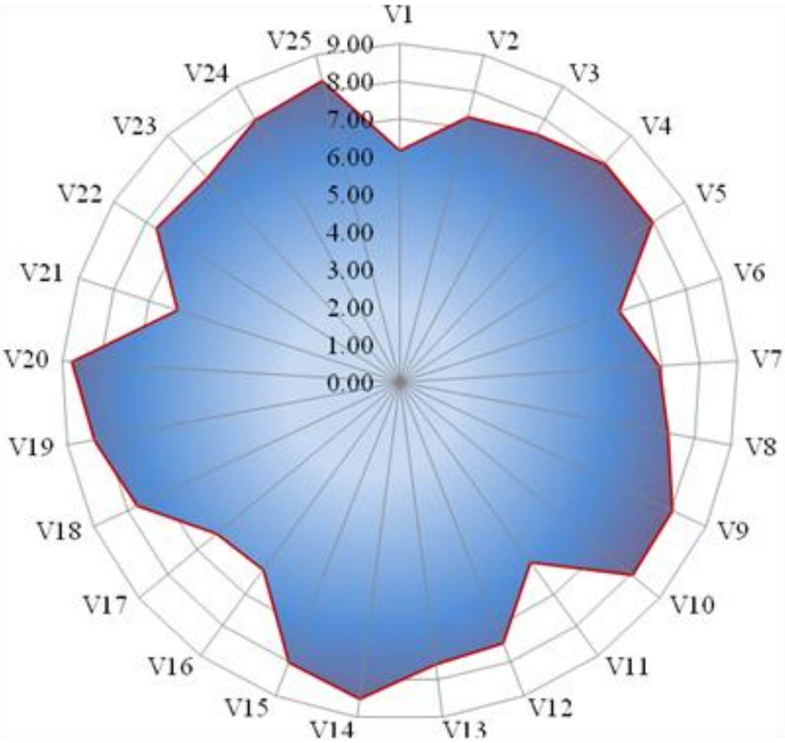


Fig. 1. The graphic distribution of the protein content (Pro, %) in corn grains in relation to mineral fertilization
Source: original graph based on experimental data.

The variation of the protein content in relation to the doses of nitrogen (N) on each level of phosphorus (P) was described by polynomial equations, under conditions of statistical safety; equation (1) described the protein variation in relation to N on the P0 fertilization level, under conditions of $R^2$=0.973, p=0.0267, F=36.355; equation (2) described the protein variation in relation to N on the P40 fertilization level, under conditions of $R^2$=0.975, p=0.025, F=38.989; equation (3) described the protein variation in relation to N on the P80 fertilization level, under conditions of $R^2$=0.924, p=0.0765, F=12.071; equation (4) described the protein variation in relation to N on the P120 fertilization level, under conditions of $R^2$=0.945, p=0.053, F=17.076; equation (5) described the protein variation in relation to N on the P160 fertilization level under conditions of $R^2$=0.854, p=0.145, F=5.8751.

$$\mathrm{Pro}_{(\mathrm{N,P0})} = -5.886E - 05x^2 + 0.02033\,x + 6.248 \qquad (1)$$

$$\mathrm{Pro}_{(\mathrm{N,P40})} = -3.2E - 05x^2 + 0.0162\,x + 6.148 \qquad (2)$$

$$\mathrm{Pro}_{(\mathrm{N,P80})} = -9.2E - 05x^2 + 0.02884\,x + 6 \qquad (3)$$

$$\mathrm{Pro}_{(\mathrm{N,P120})} = -6E - 06x^2 + 0.01538\,x + 6.006 \qquad (4)$$

$$\mathrm{Pro}_{(\mathrm{N,P160})} = -4.457E - 05x^2 + 0.01779\,x + 6.423 \qquad (5)$$

where: $x$ – nitrogen doses, kg a.s. $ha^{-1}$.

The regression analysis led to obtaining the equation (6) which described the variation of the protein content in the corn grains, in relation to N and P, as a direct and interaction effect, under statistical safety conditions, $R^2$=0.941, p<0.001, F=63.4889. The graphic representation of the protein content variation in corn grains, under the experimental conditions, is represented in the form of a 3D model in Figure 2, and in the form of isoquants in Figure 3. Based on the values of the coefficients of equation (6), the optimal values for N and P were calculated in relation to the protein content (Pro, %), and $x_{opt}$=151.20 kg $ha^{-1}$ (N), respectively $y_{opt}$=83.13 kg $ha^{-1}$ (P) were found in the experimental conditions. For high calculation accuracy, the values of the coefficients of equation (6) had values up to 16 decimal places.

$$\text{Pro} = ax^2 + by^2 + cx + dy + exy + f \qquad (6)$$

where: Pro – protein content (%);
$x$ – nitrogen dozes (N, kg ha$^{-1}$);
$y$ – phosphorus doses (P, kg ha$^{-1}$);
a, b, c, d, e, f – coefficients of the equation (6);
a= -0.00019579;
b= -0.00022802;
c= 0.07985390;
d= 0.07546559;
e= -0.00024838;
f= 0

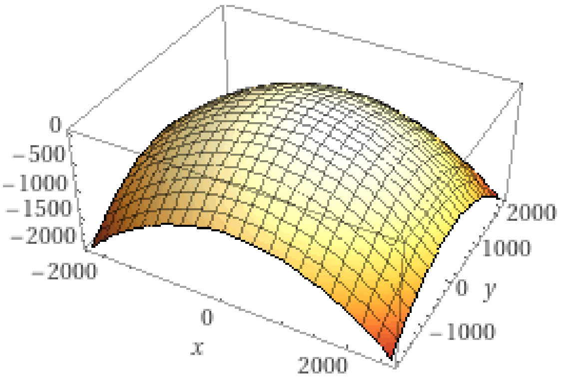


Fig. 2. 3D model of protein variation (Pro) in corn grains in relation to the doses of nitrogen N (x-axis) and phosphorus P (y-axis)
Source: original graph based on experimental data

The increase in protein content in relation to the level of nitrogen was calculated for each level of phosphorus, and the results are presented in Figure 4.

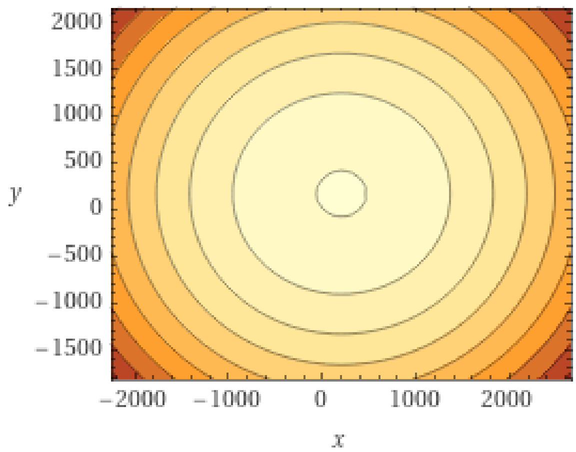


Fig. 3. Graphical representation in the form of isoquants of the variation of protein (Pro) in corn grains in relation to the doses of nitrogen N (x-axis) and phosphorus P (y-axis)
Source: original graph based on experimental data

On the P0 level, nitrogen generated an increase in the protein content between 1.13 - 1.80%, associated with nitrogen doses between 50 - 200 kg ha$^{-1}$.

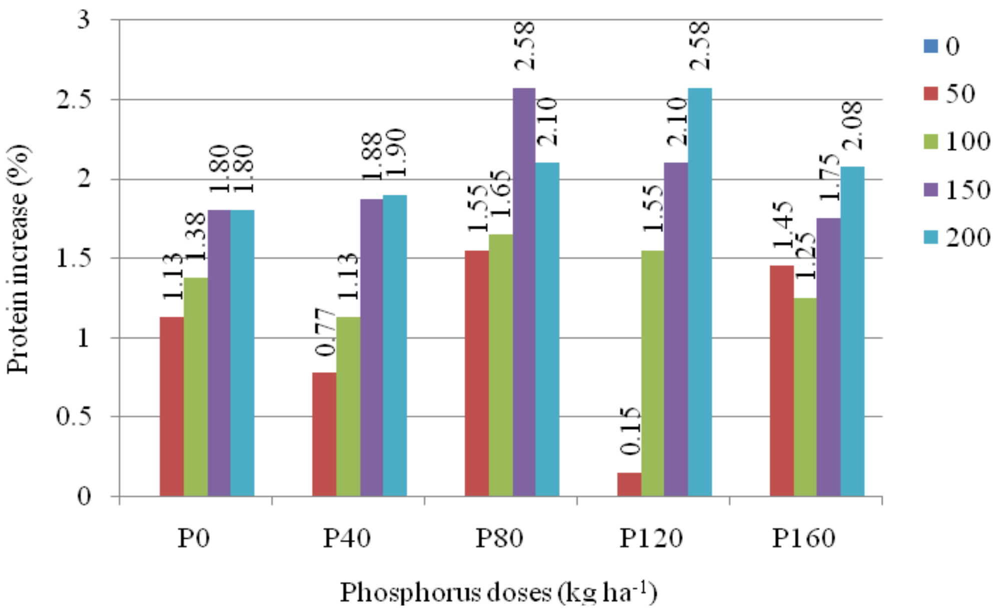


Fig. 4. The increase in protein content generated by N on each level of P, the maize DEKALB 4541 hybrid
Source: Original graph, based on calculated data.

On the P40 level, nitrogen generated an increase in the protein content between 0.77 - 1.90%, in relation to the doses of N applied (50 - 200 kg ha$^{-1}$).

On the P80 level, nitrogen applied in doses between 50 - 200 kg ha$^{-1}$ generated increases in the protein content between 1.55 - 2.58 %.

On the P120 level, the increase in protein content generated by nitrogen, in the administered doses, was between 0.15 - 2.58%.

On the P160 level, the increase in protein content determined by nitrogen, in the administered doses, was between 1.25 - 2.08%.

High values of the protein increase, obtained by calculations on the experimental variants, (Pro=2.58%) were recorded in the conditions of P80 and N150, but also in the conditions of P120, N200, Figure 4. In the version of fertilization with N200 on the level of P120, the costs are already higher with the related doses of fertilizers, so that, in terms of protein content, lower doses of fertilization, with similar results, are justified.

The cluster analysis facilitated obtaining the diagram represented in Figure 5, under conditions of statistical safety (Coph. corr=0.872). The association of variants based on Euclidean distances led to the formation of two distinct clusters (C1 and C2) with several sub-clusters within each.

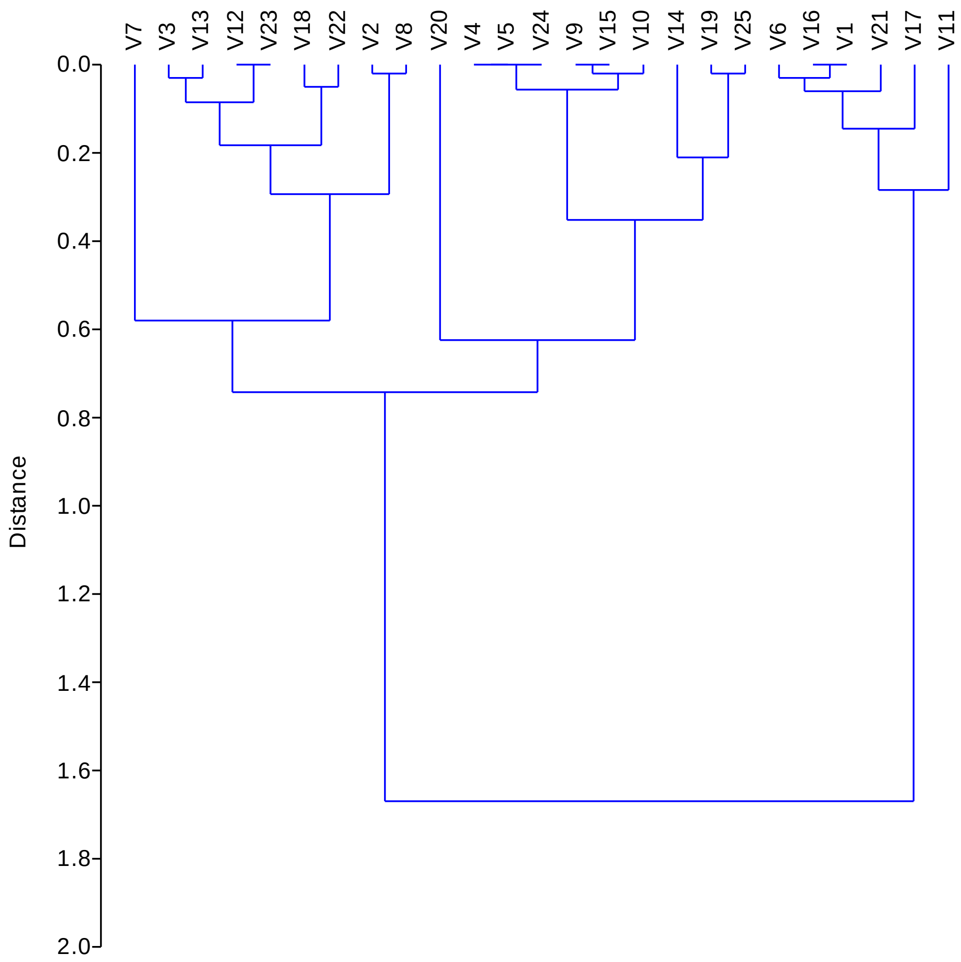


Fig. 5. Cluster diagram of variants grouping based on Euclidean distances in relation to protein content in corn grains, the DEKALB 4541 hybrid

Source: original figure based on experimental data.

Cluster C1 included variants with low protein content (V1, V6, V11, V16, V17 and V21). Within the C1 cluster, a high level of similarity was found in relation to ensuring the protein content between the V1 and V16 variants.

Cluster C2 includes variants grouped in two distinct sub-clusters (C2-A and C2-B), each with several sub-clusters.

Sub-cluster C2-A includes variants with high protein content (V4, V5, V9, V10, V14, V15, V19, V20, V24 and V25). Within this sub-cluster, a high level of similarity was found in the case of variants V4, V5, V24 and respectively in the case of variants V9 and V15. The V20 variant with the highest protein content was positioned independently within the C2-A sub-cluster.

The sub-cluster C2-B includes the variants (V2, V3, V7, V8, V12, V13, V18, V22 and V23), with intermediate values of the protein content. Within this sub-cluster, a high level of similarity was found between the V12 and V13 variants.

The variation of the quality indices, including the protein content in the corn kernels, was analyzed and evaluated in relation to N as a single fertilization, but especially N associated with macro and microelements.

Different techniques, methods and models have been used to describe and predict the variation in production, some quality indices and economic elements in corn crop, in relation to mineral fertilization or technology factors [4, 22, 29].

Căbăroiu et al., (2019) [6] communicated the variation of quality indices in corn grains under the influence of nitrogen (as mineral fertilization on the soil) associated with different doses of silicon (Si) applied foliarly, and highlighted the increase in N efficiency associated with Si, under statistical safety conditions.

The management of fertilizers (especially N) related to corn hybrids was evaluated in order to improve the protein content of corn grains [39], and the importance of fertilization in accordance with the ability of the hybrid to capitalize on fertilizing resources was highlighted.

The significant variation of protein content in corn, along with other qualitative indices, as a genotype x fertilization interaction, was communicated by Illés et al. (2020) [17], based on the use of different statistical analysis methods.

Shynkaruk and Lykhochvor (2021) [32] reported the maximum protein content (11.10%) in corn under the influence of N160P80K140, while for other quality indices (starch 74.20%, fat 4.33%), high values were recorded at lower fertilization rates (N80P40K60) under the experimental conditions.

Based on a study on quality indices in three maize hybrids (FAO middle group) under the influence of mineral fertilization, Bojtor et al (2022) [3] found that the maximum value for protein content was recorded at 120 kg N ha$^{-1}$, and higher nitrogen values did not lead to an increase in protein content under the study conditions.

Under the conditions of the present study, the applied mineral fertilization, with N and P mineral elements, generated a range of protein content values, as an interaction [genotype x fertilization].

The recorded values, associated with the fertilization variants that generated the nutritional status of the plants and the afferent protein content, grouped in the dendrogram based on the Euclidean distances, constitute an indicative basis for the selection of the different fertilization variants to obtain comparable results, in relation with the technology adopted for grain corn crop.

## CONCLUSIONS

Under the study conditions, NP mineral fertilization of the corn crop, the DEKALB 4541 hybrid, led to a set of protein content values, as an effect of the genotype x fertilization interaction, and which can constitute a reference base for research and agricultural practice.

The way of analyzing the experimental data facilitated the grouping of the variants into clusters (fertilization variant groups), with practical importance in the choice of fertilization variants in relation to the budget allocated to the corn cultivation technology, respectively in relation to the production destination and the protein level expected.

The regression analysis facilitated the obtaining of mathematical and graphical models in the form of 3D and isoquants, to describe the variation of the protein content (Pro) in relation to the two nutrition factors N and P, under conditions of statistical safety.

The calculated optimal doses ($x_{opt}$=151.20 kg ha$^{-1}$ N, respectively $y_{opt}$=83.13 kg ha$^{-1}$ P) facilitate practical recommendations to optimize the fertilization of the corn crop in relation to the expected protein content.

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# CONTRIBUTION OF THE CROP SUB-SECTORS' PERFORMANCE TO THE ECONOMIC DEVELOPMENT OF NIGERIA: THE ARDL MODEL APPROACH

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***Abstract***

*The study examined the contributions of sub-units of the crop subsector to the economic development of Nigeria (approximated by the per capita GDP (PCI)) from 1962 to 2020. The Autoregressive Distributed Lag Model (ARDL) was used to establish the existence of the cointegration among the specified series. The findings revealed that, the sub-components of the crop sub-sector co-integrate with the per capita GDP in the long run. The empirical results further revealed that in the short run, sugar-based crops gross production, vegetable, and fruit gross production have a significant relationship with the PCI in Nigeria; whereas the cereal gross production, oil-based crop gross production, sugar crop gross production, and vegetable and fruit gross production were long run significant determinants. The findings call for appropriate short and long-term economic policy packages that should stimulate investment opportunities in the crop sub-sector to increase the sub-sector's productivity for greater economic development stimulation.*

**Key words:** *agriculture, crop sub-sector, economic development, Nigeria*

## INTRODUCTION

Despite the wavering opinions of various schools of thought [28, 19] regarding the contributions of the agricultural sector either in the short or long run periods to the development of the African economy; the sector is noted to play important roles in the economic development of the majority of African countries [46, 21, 34, 2, 4, 32]. Though in Africa, the sector is clouded by emerging challenges (such as the vast global technological changes, conflicts, climate change, extreme poverty, corrupt governance, natural disaster, the changing pattern of consumption, dynamic international trade policies, etc.) that have seriously impacted on many of the fundamentals that have supported the sector over the past decades; it is still a major livelihood source to majority of resource-poor vulnerable populations in the region [35, 27, 1, 8, 20]. In Sub-Saharan Africa, the sector is largely dominated by small-scale farmers who utilized obsolete tools in fragmented land space and harbour about 60 - 70% of the region's labour force [17, 39, 3].

In Nigeria, despite the enormous challenges hovering over the agricultural sector, the literature has persistently documented the positive roles the sector has played in terms of its contribution to the country's GDP, food security, employment generation,and stimulation of primary product exports [7, 11, 14, 15]. The sector is also known to attract a considerable volume of imports, thereby constituting a catalyst for international trade [6]. Being a traditional sector, it is mostly considered a reliable source of raw materials for industrialization through its backward linkages.

Traditionally, the agricultural sector consists of further subsectors or components that are interrelated in function and resource utilization. For instance, in Nigeria, there are four major subunits of the agricultural sector. These are the crop, forestry, livestock, and fishery sub-units [23, 18]. Among the subunits, the crop subunit appears to be the most prominent and significant in terms of its contribution to the total value product of the agricultural sector in Nigeria [18]. As noted by Urama and Nfor, [45] and supported by the data shown in Table 1, the crop subunit has been the major driver of the agricultural sector and significantly impacted the economy GDP in Nigeria by contributing an average of about 84.23% and 19.74% of the total agricultural GDP component and the economy GDP respectively from 1981 to 2019.

Table 1. Contributions of crop sub-sector to the agricultural and total GDP in Nigeria

| Year | Average % contribution of Crop sub-sector GDP in Agric. GDP | Average % contribution of Crop sub-sector GDP in total GDP |
|---|---|---|
| 1981 – 1985 | 71.812 | 10.756 |
| 1986 – 1990 | 79.685 | 16.516 |
| 1991 – 1995 | 83.944 | 19.651 |
| 1996 – 2000 | 84.521 | 22.955 |
| 2001 – 2005 | 88.967 | 27.203 |
| 2006 – 2010 | 89.530 | 22.932 |
| 2011 – 2015 | 88.316 | 18.804 |
| 2016 – 2019 | 88.236 | 18.933 |
| Overall Average | 84.277 | 19.739 |

Source: Computed by the author data from the Central Bank of Nigeria, 2021 [18].

The dominant roles of the crop subunit in the total value of the agricultural sector in Nigeria are traceable to various factors including; availability of farm resources, cultural values and demand preference among others [5, 16]. The diet composition of the majority of Nigerians is majorly dependent on crop composition due to its affordability, availability, and perceived utility that is often traditionally linked [36].

Additionally, the crop sub-units have enjoyed the patronage of the federal, state, and local government authorities in terms of policy formulation and implementation [4]. For instance, the agricultural policies and programmes landscape of Nigeria is highly skewed in favour of the crop subunit compared to other sub-sectors [7, 40, 30]. The response of the crop sub-sector vis-a-vis the agricultural policy environment over the years had produced some mixed outcomes [7,41,6, 44, 1]. The individual crop response to the policy environment is mostly measured and replicated in the growth rate of the outputs within the policy period.

Table 2 shows the average annual growth rates of selected crops vis-à-vis the agricultural policy environment from 1961 to 2019 in Nigeria. It is obvious that; the responses did not assume a similar pattern across the policy periods. There is a conspicuous difference in magnitude and sign of the growth rates of crops across the specified policy periods. Each crop component showed a unique pattern of response as measured by the growth rate across the specified policy periods. For instance, cassava experienced positive growth rates throughout the specific policy era, whereas yam witnessed a deteriorating growth rate in the period 1972 to 1981. From the evidence given in Table 2, it is deduced that within the crop-sub sector; some categories of crops played more significant roles than others in propelling the aggregate agricultural GDP component and the entire economy GDP alike. This issue of crop sub-sector components' contribution to the economic growth of Nigeria has often bred bias in the choice of policy intervention by policymakers but the matter is rarely examined empirically.

Hence, empirically identifying the extent of the contributions of the sub-components of the crop sub-sector to the economic development of Nigeria would amount to an increase in the potency of the sub-sector and probably prioritise policy direction in the subsector. Thus buttressed on this assertion, the study was designed to isolate the roles of the various categories of the crop sub-sector in driving the economic development of Nigeria. The importance of the study is based on the fact that; the country needs more specific and proactive policy action to fast-track the anticipated agricultural development. Again, there is an overwhelming need to reassess the areas of comparative advantage in crop enterprises; the disaggregated performance of the crop sub-sector in addition to appraising the efficacy of the institutional and technological resilience of the crop subsector in the country.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Nigeria. The country is situated on the Gulf of Guinea in sub-Saharan Africa. It lies between $4^0$ and $14^0$ north of the equator and between longitude $3^0$and $15^0$ east of the Greenwich. The country has wet and dry seasons that support varieties of vegetation and thus agricultural production. The country's agricultural sector produces different types of crops and animals and has contributed significantly to the overall economic development of the country. The agricultural sector is the largest employer of labour but largely depended on small-scale productions.

Table 2. Linear growth rates/fluctuations in selected Agricultural Products in Nigeria

| Agricultural product | Policy periods and linear growth rates of crops in Nigeria (%) | | | | | | Average linear growth rate (%) from 1970 to 2019 |
|---|---|---|---|---|---|---|---|
| | 1962 - 1971 | 1972 - 1981 | 1982 - 1991 | 1992 - 2001 | 2002- 2011 | 2012 - 2019 | |
| Oil palm | -2.00 | -0.44 | 2.78 | 2.75 | -0.58 | 2.89 | 0.83 |
| Coconut | 3.17 | 0.58 | 2.71 | 2.25 | 5.15 | -1.46 | 2.19 |
| Maize | 2.16 | 5.37 | 25.92 | -1.59 | 7.04 | 3.05 | 7.12 |
| Rice | 16.89 | 18.94 | 11.98 | -0.94 | 6.42 | 8.42 | 10.35 |
| Yam | 11.63 | -5.11 | 15.33 | 4.58 | 3.22 | 5.75 | 5.90 |
| Cassava | 2.33 | 1.95 | 9.69 | 2.18 | 4.12 | 3.46 | 3.97 |
| Groundnut | -0.50 | 3.24 | 12.19 | 7.82 | 2.13 | 6.73 | 5.22 |
| Cotton | 6.63 | 3.68 | 24.78 | 4.67 | 5.29 | -8.21 | 6.63 |
| Cocoa | 6.23 | -3.34 | 6.26 | 6.77 | 1.98 | -1.18 | 2.92 |
| Rubber | 1.41 | 1.15 | 12.42 | -2.98 | 3.29 | 0.41 | 2.69 |
| Cashew | 16.27 | 0 | 7.00 | 32.48 | 2.25 | -15.94 | 7.80 |
| Vegetables | 3.26 | -1.22 | 7.97 | 7.55 | 4.66 | 2.76 | 4.21 |
| Pineapple | 2.00 | 0 | 3.03 | 1.07 | 6.06 | 1.54 | 2.31 |
| Tomatoes | 2.49 | 4.31 | 1.42 | 13.09 | 2.77 | 18.73 | 6.74 |
| Other fresh fruits | 2.44 | 2.39 | 3.57 | 3.01 | -2.94 | -1.37 | 1.27 |

Source: Computed by the author data from the FAO [17] and World Bank, 2020 [46].

The country has a total land area of about 923,769km$^2$ (or about 98.3 million hectares) with 853km of coastline along the northern edge of the Gulf of Guinea and a population of around two hundred (200) million [38]. Its multiple vegetation zones, plentiful rain, surface water, underground water resources and moderate climatic extremes, allow for the production of diverse food, tree and cash crops. Over 60 percent of the population is involved in the production of the food crops such as cassava, maize, rice, yams, various beans and legumes, soya, sorghum, ginger, onions, tomatoes, melons and vegetables. Also, fishery, aquaculture and livestock production such as poultry, goat, sheep, pigs and cattle flourished very well in all regions of the country. The main cash crops are cocoa, cotton, groundnuts, palm oil, and rubber [26].

**Data source**

Secondary data were used and were sourced from the World Bank and Food and Agricultural Organization (FAO) as well as the Central Bank of Nigeria. It covered the period from 1961 to 2020.

**Analytical Technique**

The relationship between the crop sub-sectors and the economic development of Nigeria was captured by the equation that relates crop sub-sector gross production indices and the GDP per capita (an economic development indicator). The specified equation assumes the following Cobb-Douglas implicit forms as thus:

$$PCI_t = f(CER_t, OCR_t, RTC_t, SUC_t, VAF_t) \dots\dots (1)$$

where:

$PCI_t$ = Gross domestic product per capita to capture the economic development of Nigeria (N/Person)
$CER_t$= Cereal gross production index (%) (2014 - 2016 =100)
$OCR_t$ = Oil crop gross production index (%) (2014 - 2016 =100)
$RTC_t$ = Root and Tuber crop gross production index (%) (2014 - 2016 =100)
$SUC_t$ = Sugar crop gross production index (%) (2014 - 2016 =100)
$VAF_t$ = Vegetable and Fruit gross production index (%) (2014 - 2016 =100)

**The Autoregressive Distributed Lag (ARDL) bound test**

The Autoregressive Distributed Lag (ARDL) bound test was developed by Pesaran and Shin [42] and Pesaran*et al.*[43] to investigate the long and the short-run relationship among variables. The ARDL bound model has three advantages when compared with the conventional Engle and Granger [25] two-step method and Johansen and Juselius [31] cointegration method. The ARDL method is designed to deal with the series having mixed stationary issues (i.e. the mixture of 1(0) and 1(1)). Hence, it relaxes the assumption that all series must be integrated in the same order. The second advantage of ARDL test over other methods is that it generates relatively more efficient estimates in the case of small and finite sample data sizes. Thirdly, the method produced unbiased estimates of the long-run model [29]. The ARDL model for equation (1) in logarithmic form is expressed as follows: The specification of the ARDL model assumes endogeneity of the specified variables, hence the model was also applied to the rest of the variables in equation (1).

$$\begin{aligned}\Delta PCI_t &= \beta_0 + \beta_1 \sum_{i=1}^{n_1} \Delta PCI_{t-1} + \beta_2 \sum_{i=1}^{n_2} \Delta CER_{t-i} \\ &+ \beta_3 \sum_{i=1}^{n_3} \Delta OCR_{t-i} + \beta_4 \sum_{i=1}^{n_4} \Delta RTC_{t-i} + \beta_5 \sum_{i=1}^{n_5} \Delta SUC_{t-i} \\ &+ \beta_6 \sum_{i=1}^{n_6} \Delta VAF_{t-i} + \delta_1 PCI_{t-i} + \delta_2 CER_{t-i} + \delta_3 OCR_{t-i} \\ &+ \delta_4 RTC_{t-i} + \delta_5 SUC_{t-i} + \delta_6 VAF_{t-i} \\ &+ U_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . (2)\end{aligned}$$

The coefficients from $\beta_1$ to $\beta_6$ represent the short-run coefficients whereas the coefficients from $\delta_1$ to $\delta_6$ represent the long-run coefficients of the ARDL model. Also, $\beta_0$ is the drift component, "n" is the maximum lag length while $U_t$ is the stochastic error term.

The bounded F-statistic test was used to check the existence of a stable, long relationship among the variables in the models. For instance, if the calculated F-statistic in equation (2) is greater than the appropriate upper bound critical values, the null hypothesis is rejected implying the existence of the co-integration relationship. But if the value of the F-statistic is below the lower bound, the null cannot be rejected, indicating the absence of co-integration. Besides, if the F-statistic value lies within the lower and upper bounds, the results are considered inconclusive [43]. If the bound test shows evidence of co-integration among variables, then the long and the short-run(an error correction model (ECM)) are specified as follows:

The long run model:

$$\begin{aligned}PCI_t = \delta_0 + \delta_1 PCI_{t-i} + \delta_2 CER_{t-i} + \delta_3 OCR_{t-i} \\ + \delta_4 RTC_{t-i} + \delta_5 SUC_{t-i} + \delta_6 VAF_{t-i} \\ + U_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots . \ldots . . (3)\end{aligned}$$

The short run model (ECM model):

$$\begin{aligned}\Delta PCI_t = \beta_0 + \beta_1 \sum_{i=1}^{n_1} \Delta PCI_{t-1} + \beta_2 \sum_{i=1}^{n_2} \Delta CER_{t-i} \\ + \beta_3 \sum_{i=1}^{n_3} \Delta OCR_{t-i} + \beta_4 \sum_{i=1}^{n_4} \Delta RTC_{t-i} \\ + \beta_5 \sum_{i=1}^{n_5} \Delta SUC_{t-i} + \beta_6 \sum_{i=1}^{n_6} \Delta VAF_{t-i} \\ + \emptyset ECM_{t-1} + U_t \ldots\ldots\ldots\ldots (4)\end{aligned}$$

where Ø is the error correction term and its measures the speed of adjustment towards the long-run equilibrium, and the remaining coefficients provide the short-run dynamics. To access the performance of the estimated model, the RESET test, Serial correlation, normality and Heteroscedasticity tests were conducted, whereas the cumulative sum (CUSUM) test was estimated to verify the stable nature of the model.

## RESULTS AND DISCUSSIONS

### Descriptive Statistics

The descriptive statistics, as presented in Table 3, revealed that the coefficient of variability in the cereal gross production index, oil crop gross production index, root and tuber crop gross production indices, sugar crop production index and vegetable and fruit gross production index was less than 100% respectively. The variability index was 50.00% and 38.00% in oil crop and sugar crop gross production indices respectively. However, per capita income (PCI) showed an explosive coefficient of variability that suggests it was so unstable over the period specified in the study. The degree of skewness revealed positive skewness in all specified variables except the cereal crop gross production index. It implies that these variables experienced a continuous increments in their annual values over the specified period of time.

Table 3.Descriptive Statistics of Variables Used in the Estimated Models

| **Variable** | Mean | C.V. | Skewness | Minimum | Maximum |
|---|---|---|---|---|---|
| CER | 63.49 | 0.47 | -0.01 | 22.29 | 116.77 |
| OCR | 56.11 | 0.50 | 0.34 | 20.03 | 118.76 |
| RTC | 44.68 | 0.71 | 0.52 | 11.37 | 104.22 |
| SCR | 59.32 | 0.38 | 0.57 | 13.00 | 104.00 |
| VEF | 52.06 | 0.51 | 0.64 | 21.22 | 103.08 |
| PCI | 1.32e+05 | 1.61 | 1.53 | 69.43 | 7.25e+05 |

Source: Computed by the author data from the FAO [17] and World Bank, 2021 [46].

**Unit root test**

The study used the ADF test developed by Dickey and Fuller [22] and the ADF-GLS unit root test developed by Elliott, Rothenberg and Stock [24] which is an improvement of the original ADF test to confirm the unit root of the specified variables. The results for both ADF and ADF-GLS unit root tests are presented in Table 4. The results revealed that the sugar crop gross production index (SCR) was stationary at levels, while the rest of the variables were stationary at the first difference in the ADF test. All variables were stationary at the first difference for the ADF-GLS test (Note the test equations contain both constant and trend). Since we have a mixture of variables that are 1(0) and 1(1), it implies that the ARDL model can be used to test for co-integration in the specified model.

Table 4. ADF and ADF-GLS unit root tests on variables used in the specified equations

| Variable | ADF (constant and trend) | | | ADF-GLS (constant and trend) | | |
|---|---|---|---|---|---|---|
| | **Level** | **1st Diff.** | **Decision** | **Level** | **1st Diff.** | **Decision** |
| CER | -2.372 | -9.089*** | 1(1) | -2.283 | -9.209*** | 1(1) |
| OCR | -2.249 | -11.908*** | 1(1) | -1.691 | -12.007*** | 1(1) |
| RTC | -1.298 | -6.702*** | 1(1) | -1.287 | -6.566*** | 1(1) |
| SCR | -4.071** | - | 1(0) | -1.834 | -5.098*** | 1(1) |
| VEF | -2.989 | -10.249*** | 1(1) | -2.608 | -10.354*** | 1(1) |
| PCI | -1.528 | -6.226*** | 1(1) | -1.4133 | -6.102*** | 1(1) |

Source: computed by the author.

Note: ***, ** and * indicate 1%, 5% and 1% significance levels respectively. Note, that variables are expressed in a natural logarithm.

The optimal lag lengths for the ARDL model were determined by using the Akaike Information Criterion (AIC), Schwarz, and Bayesian Criterion (SBC). The various lag lengths are shown in Table 4.

The calculated F-statistics for the specified equation are presented in the upper portion of Table 5.

Note, that each of the variables in the PCI equation was tested, but the results of the equation of our interest are presented for the discussion.

The Results of F-statistics for the specified equation revealed that cointegration exists among the variables specified. The calculated F-statistics for these equations were greater than the tabulate upper bound critical value at a 1% level of significance.

The findings imply that long-run equilibrium stable equations exist for the specified PCI equation.

Consequently, the short run or the ECM model can be generated from the equation to capture the dynamics in the PCI equation in the short run and identified the speed of adjustment as a response to departure from the long-run equilibrium.

Table 5. ARDL Bound Test (unrestricted intercept and no trend)

| Equations | Lag | F-Statistic | Decision |
|---|---|---|---|
| $F_{PCI}$ (PCI│CER, OCR, RTC, SUV, VAF) | (1,1,1,1,1) | 14.37883 | Co-integration |
| **Critical Values Bound (at K = 5 and n = 59)** | | | |
| | Lower | Upper | |
| 10% | 2.204 | 3.210 | |
| 5% | 2.589 | 3.683 | |
| 1% | 3.451 | 4.764 | |

Source: computed by the author using Eviews 10 and data as described in Equations 1, 2, and 3. Critical values are derived from Narayan, [37]. Note, that variables are expressed in a natural logarithm.

## The Long-run Coefficients of ARDL for the PCI equation

Subsequent to the establishment of co-integration for the specified equation, Table 6 presents the long-term coefficients of the ARDL model. The results revealed that the economic development of Nigeria proxy by the per capita income (PCI) has a positive and significant (at 1%) long-run relationship with the cereal gross production index. This means that a one percent increase in the cereal production index will lead to a 0.812 percent increase in the PCI. The result implies that an increase in the production of cereal will add to or constitutes one of the sources of the improved well-being of Nigerians in the long run.

In the like manner, the production of vegetables and fruits exhibited a positive long-run correlation with the indicator of economic development in Nigeria. This connotes that, an increase in the production of fruit and vegetable will significantly add to the improvement of the general well-being of Nigerians in the long run. Based on the magnitude of the estimated coefficient, it seems that vegetable and fruit production are better stimulants of economic development or well-being of Nigerians compared to other crop sub-sectors.

Table 6. The Long- run Coefficients of Economic development (PCI) equation

| Variable | Coefficient | Std. error | t-value | Probability |
|---|---|---|---|---|
| Constant | −13.8171 | 1.1754 | −11.76*** | <0.0001 |
| Cereal crop gross prod index | 0.8117 | 0.25194 | 3.222*** | 0.0022 |
| Oil crop gross prod index | −0.7214 | 0.2469 | −2.921*** | 0.0051 |
| Root and tuber crop gross prod index | −0.2026 | 0.25402 | −0.7976 | 0.4287 |
| Sugar Crop gross prod index | −0.6539 | 0.26993 | −2.422** | 0.0189 |
| Vegetable & Fruit crop prod index | 6.7159 | 0.4828 | 13.91*** | <0.0001 |

Source: computed by the author. Note: ***, and ** indicate 1% and 5% significance level respectively. Note, that variables are expressed in a natural logarithm.

The long-run coefficient of the oil-based crop gross production index showed a negative significant relationship with the PCI at a 1% probability level. By implication, a unit increase in oil-based based crop gross production index would lead to about 0.721 decreases in the index of economic development of Nigeria. The finding reveals that, though the production of the oil-based crops has a significant relationship with PCI in the long run, it moves in an opposite direction to PCI. An increase in the importation of palm oil and its derivatives could likely cause this relationship. Related results have been reported by [9, 10, 11, 12, and 13].

In a similar manner, the coefficient of the sugar-based crop gross production index has a significant negative impact on the PCI. A unit increase in the sugar-based gross production index reduces the PCI by 0.654 units. This means that increase in sugar production has a deteriorating effect on the well-being of Nigerians in the long run. The plausible reason for the result could be connected to the fact that the bulk of the refined sugar produced in the country is deduced from the imported semi-processed or concentrate forms. The importation of semi-processed sugar over the years has brought a great financial burden to the country and this has a serious implication on the overall growth of the Nigerian economy.

The slope coefficient of the root and tuber crop gross production index shows a negative insignificant effect on PCI in the long run.

The finding implies that the production of root and tuber crops does not significantly influence the movement of PCI in the long run though they are co-integrated.

**The Error Correction Model of the ARDL for the PCI equation**

The result in Table 7 presents the error correction representation of the ARDL model for equation 1. The coefficient of the error correction term is negative and statistically significant at a 5% probability level, which implies the existence of co-integration among the variables included in the ARDL model. It indicates that about 17.91% of the short-run disequilibrium is adjusted towards its long-run equilibrium annually. The diagnostic test for the ECM model revealed an $R^2$ value of 0.1715 which means that the specified explanatory time series explained about 17.15% of the adjusted total variations in the PCI in Nigeria. The F-statistic of 2.59 is significant at a 5% probability level, indicating that the $R^2$ is significant and this implies that the equation has the goodness of fit. The Durbin-Watson value of 1.977 indicates almost zero serial correlation. The ECM model has been shown to be robust against residual autocorrelation. Therefore, the presence of autocorrelation does not affect the estimates [33]. Also, the RESET test confirms the structural rigidity of the estimated model. The residual is normally distributed and this justified the use of the OLS estimation method. The Breusch-Pagan and CUSUM tests showed no evidence of heteroscedasticity and attest to the stability of the estimated model respectively. The empirical result revealed that the quantity of vegetables and fruits produced is a positive determinant of economic development in Nigeria in the short run. A unit increase in the quantity of vegetables and fruits produced will trigger about 1.2703 units increase in the index of economic development in the short run.

Table 7. The short - run Coefficients of Economic development (PCI) equation

| Variable | Coefficient | Standard error | t-value | Probability |
|---|---|---|---|---|
| Constant | 0.0937 | 0.0352 | 2.663** | 0.0105 |
| $\Delta PCI_{t-1}$ | 0.2268 | 0.1002 | 2.265** | 0.0280 |
| $\Delta CER_t$ | 0.0792 | 0.1142 | 0.694 | 0.4909 |
| $\Delta OCR_t$ | 0.0951 | 0.1048 | 0.907 | 0.3688 |
| $\Delta RTC_t$ | 0.0023 | 0.1726 | 0.013 | 0.9895 |
| $\Delta SCR_t$ | −0.2067 | 0.1027 | −2.013** | 0.0497 |
| $\Delta VEF_t$ | 1.2703 | 0.6012 | 2.113** | 0.0397 |
| $ECM_{t-1}$ | −0.1791 | 0.0689 | −2.598** | 0.0123 |
| **Diagnostic Test** | | | | |
| R-Squared | 0.1715 | Durbin-Watson | | 1.977 (0.45) |
| F(7, 49) | 2.597 (0.023) | Normality of residual | | 43.378(0.00) |
| RESET test | 0.2613 (0.77) | LM test for autocorrelation | | 0.023(0.88) |
| Breusch-Pagan | 11.7041 (0.11) | CUSUM test | | 0.3941(0.69) |

Source: computed by the author.

Note: ***, and ** indicate 1% and 5% significance level respectively. Note, that variables are expressed in a natural logarithm.

The short-run coefficient of the sugar crop production relates negatively to the index of economic development in Nigeria. A similar result was obtained for the long-run relationship. The plausible reasons are the heavy dependence on semi-processed sugar imports and the financial implication of such international transactions on the Nigerian economy. Similar assertions have been reported by [9, 10, 11, 12, and 13].

The CUSUM plot from a recursive estimation of the ECM model is shown in Figure 1. This indicates stability in the estimated ECM coefficients over the specified period as the plot of the CUSUM statistic lies within the critical band of the 95% confidence interval of parameter stability.

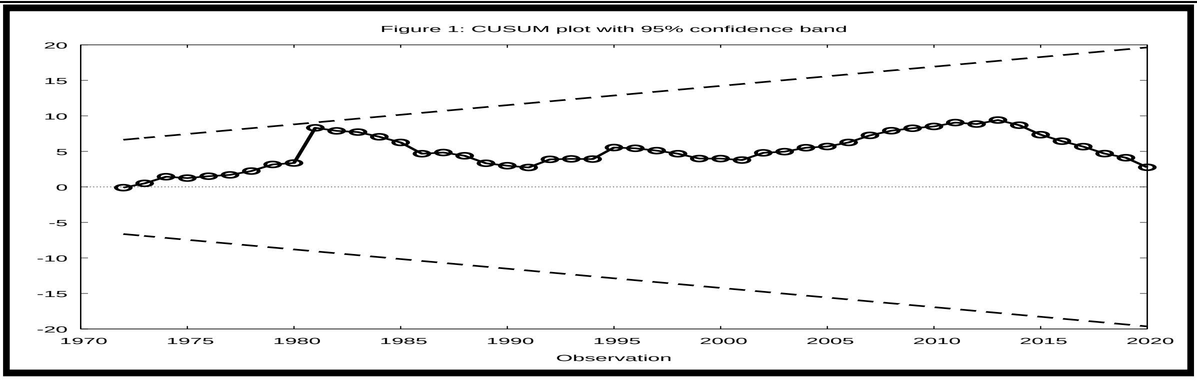


Fig.1. The CUSUM plot with a 95% confidence interval
Source: Generated from data analysis

## CONCLUSIONS

The study has established the empirical relationship between the crop subunits and indicators of economic development in Nigeria. The time-series data properties were analysed using the Augmented Dickey-Fuller unit root test and improved ADF-GLS unit root test. The result indicated that the specified series have a mixed stationarity issue (i.e. I (0) and 1 (1)). Based on the behaviour of the series, the ARDL model was used to establish the cointegration among series. The existence of cointegrations among series was established and the long and short runs coefficients of the specified PCI equation were generated. The error term from the short-run model had an appropriate sign and was statistically significant at the conventional probability level. The empirical findings confirmed the co-movement of the specified components of the crop sub-sector and the per capita GDP in the Nigerian economy in the long-run period. This connotes that, these variables were somehow interdependent in the long run.

Precisely, the empirical findings revealed that the cereal gross production, oil crop production, sugar crop production, and vegetable and fruit crop production are significant long run determinants of the per capita income (economic development indicator) in Nigeria. However, the sugar crop production relates in a negative manner to economic development and was plausibly linked to heavy reliance on importation with its attendance negative effect on the country’s GDP. The short rum model reveals that vegetable and fruit crop production as well as the sugar crop are the short-run determinants of PCI. The study also established the fact that vegetable and fruit crop production has a more impacting relationship with the economic well-being of Nigerians both in the short and long-run periods compared to other subunits of the crop sub-sector. The findings of the study suggest that the crop sub-sector played significant roles in the economic development of Nigeria in both short and long-run periods. The findings imply that; the country needs to improve the policy framework on crop production by emphasizing more on the increase in output of all crops. This could be achieved by focusing on modern and improved techniques of production across the crop sub-sector value chain.

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# TRENDS IN MAJOR RUMINANT MEATS PRODUCTION AND THE ROLES OF THE MACROECONOMIC ENVIRONMENT IN NIGERIA

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***Abstract***

*This study analyzed the trends in major ruminant meats (beef, chevon, mutton, and total ruminant meat) and provided empirical evidence on the relationship between ruminant meats production and key macroeconomics fundamentals in Nigeria. The study employed the time-series data that were sourced from the Food and Agricultural Organization (FAO), Central Bank of Nigeria,and the World Bank and ranging from 1961 to 2021. The descriptive analyses, trend equation, and multivariate autoregressive model were used to analyze the data. The result of the data analyses revealed an annual exponential growth rate of 1.156%, 6.694%, 6.032%, and 2.747% for beef, chevon, mutton, and total ruminant meat respectively. The empirical outcomes showed that the annual inflation rate has a significant negative inelastic association with the ruminant meats production in Nigeria; while the per capita income had a significant positive inelastic relationship. Moreover, the annual nominal exchange rate exhibited a mixed effect on ruminant meat production. To improve ruminant meat production in the country, it is strongly suggested that the inflation rate should be moderated and the country should develop sound and efficient policies to increase the per capita income.*

***Key words:*** *meat, ruminant, trend, macroeconomic, Nigeria*

## INTRODUCTION

Ruminants are even-toed, hoofed, four-legged herbivorous animals that chew the cud and have complex stomach systems [22, 32]. Examples of widely domesticated and economic ruminants in Nigeria include cows, sheep, and goats. In Nigeria, apart from fish, ruminants are the major sources of animal protein available [35, 37, 2]. They are basically reared for meat, milk, and other by-products. They played intermediary and important functions in the food chain and sustainable agricultural system respectively [32]. They are the major constituent of the country's livestock. In 2020, there were about 83.7 million goats; 47.7 million sheep; and 20.7 million cattle heads in Nigeria [24]. Ruminant meats in 2020 make up 57.02% of the total meat produced in the country [24]. Excluding chicken meat, it constituted about 66.15% of the total meat produced in 2020. In 2020, the total meat produced in Nigeria was 1.72 million tonnes. Total production of meat in Nigeria declined from 1.75 million tonnes in 2018 to 1.74 in 2019 and 1.72 million tonnes in 2020 and deaccelerated at an average annual rate of 0.86% [24]. Nigeria's meat production is challenged by low-value addition attributed to poor processing infrastructures and an unregulated market system characterized by price volatility in the spatial markets [12].

Available records revealed that in the last three decades, the consumption of meats in Sub-Saharan Africa and Nigeria, in particular, has witnessed an upsurge [24].

The surge in consumption of meats emanated from several factors, such as increasing urbanization, youthful population, improved educational status, rising personal income, and socialization among others. Irrespective of the growing demand for meats in the country, its production is still majorly small scale and is characterized by declining annual output growth [24, 9] (Figure 1).

According to the report of FAO, [26] and FAO, [28], about 40 percent of households in Nigeria are responsible for producing the bulk of the meat consumed, with the exception of poultry meat.

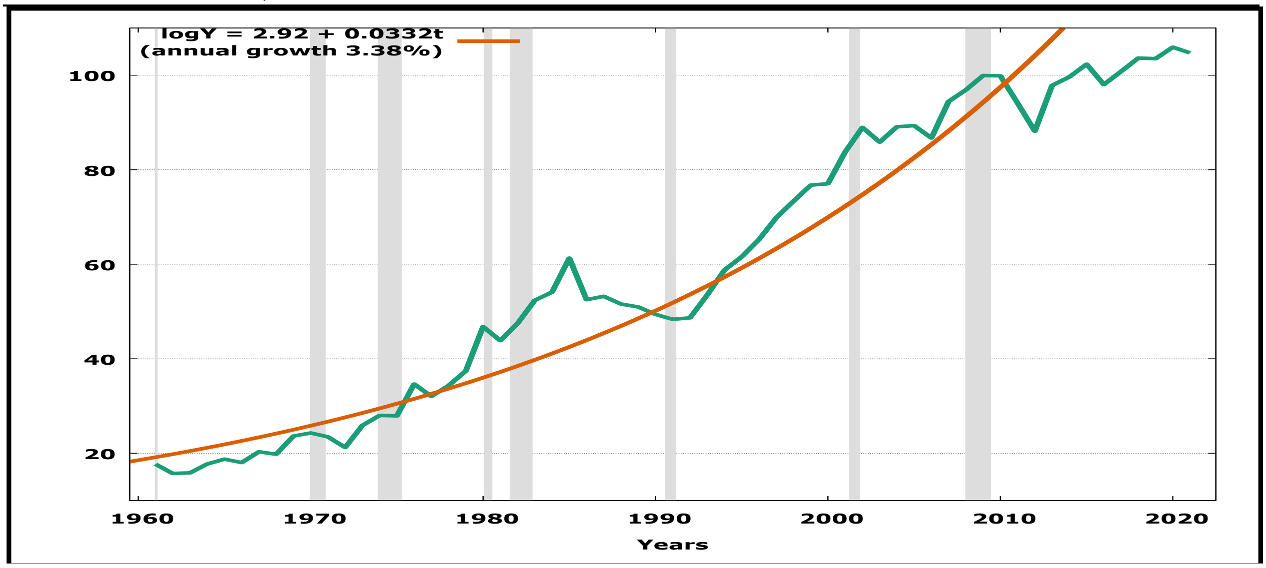


Fig.2. Trend in Total Meat Production Index in Nigeria (2001 - 2016) = 100.
Source: Data from FAO, 2022.

Following Agboola & Balcilar [1], Babatunde & Qaim [19], the country's livestock industry is small and slow-growing relative to the population relying on it for meat. As shown in Figure 1, the total meat production index assumed undulated growth rate from 1960 to 2021 with sharp depressions in 1991 and 2012.

Given the country's annual population growth rate of 2.57% and the current population of over 200 million [34, 10] in addition to the 3.38% annual growth rate (Figure 1) in total meat production, there are serious issues in meeting the protein demand of the majority of Nigerians now and in the future. The majority of the animal farmers in the country are resource-poor; lack adequate veterinary services and are affected by changing climatic and environmental conditions among others [6, 16]. In the country, both population and infrastructures are expanding, culminating in an unprecedented increase in overall demand capacity for protein sources especially meats, but without a corresponding increase in meat production [8]. The majority of the population (being youthful) is rapidly adopting the consumption pattern that is anchored on diets rich in meat and other animal derivatives [13, 18]. Following these occurrences, there is an unprecedented increase in the demand for meat and their derivatives with the urgent need to augment domestic production if the minimum protein requirement of Nigerians is prioritized. To bridge the shortfall in domestic production of meats in the country, issues related to poor infrastructures, farmers' poverty alleviation, improved breeding programs, and genetic engineering as well as ranch development among others are required [32, 5]. Since, the ruminants' production is done mostly by nomadic and semi-nomadic pastoralists, implementing sustainable policies is a serious challenge to Nigeria's government. Currently, there are several nomadic pastoralists – farmers' conflicts which many analysts believe is one of the major causes of the declining ruminant production trend in the country [22, 32].

Available statistics have shown that Nigeria's average per capita meat consumption is approximated at 9.0kg per person per year [25, 27, 24]. The index is less than the continental average of 19.0kg and the World Health Organization (WHO) minimum standard of protein consumption (0.83g/kg of body weight per day of protein) for an adult [27]. The federal government of Nigeria has enunciated several policies and programs to tackle the problems of protein deficiency among Nigerians. For instance, the national livestock transformation plan programs was set up with the aim to increase the output of animal-based protein sources and provide a roadmap through which a holistic transformation of the livestock sub-sector will be achieved till 2027 [39, 34, 15].

However, the anticipated transformation of the livestock sub-sector through the adequate supply of meats and generating effective demand depends, among other things, on previewing and understanding the trends in production as well as the efficient, and stable macroeconomic environment [14]. Hence, this calls for a concerted effort to relate the trends in meats production and the macroeconomic fundamentals that are critical in influencing activities in the real sector of the economy. For instance, improving per capita income is a prerequisite for driving effective demand for agricultural products including meats in developing countries [17, 4, 27, 23, 28]. Furthermore, as noted by Simo-Kengne*et al.*, [36], the price of meat, gross domestic product (GDP), inflation rate, exports, imports, and urbanization are the major variables that affect meat consumption. Besides, Akpan *et al.*, [14], opined that an increase in the per capita income, total exports, external reserves, inflation rate, and external debt influence agricultural production negatively in both short and long-run periods; whereas the industry's capacity utilization rate and nominal exchange rate relate positively in both long and short-run periods. Also, Akpan et al., [11] showed that the rate of inflation, external reserves, per capita income, industrial production, and energy consumption affect agricultural intensification adversely. The findings also noted that the annual inflation rate, industrial output, and external reserves reduce agricultural intensification in the short-run period. Additionally, Akpan and Umoren [9] established the empirical relationship between some key macroeconomic variables and meat as well as the milk gross production indices in Nigeria. The empirical results showed that the per capita income, nominal exchange rate, and land density were the determinants of meat gross production index in the long run, whereas, per capita income, credit to the economy, and land density were identified as the short-run determinants. Furthermore, Betru and Kawashima [21] submitted the determinants of meat consumption in Ethiopia. The result showed that urbanization and per capita income were positive and significant determinants of meat consumption in Ethiopia.

In addition, James et al., [31] analyzed beef demand drivers and enhancement opportunities in the United States of America. They found a positive significant relationship between U.S. consumer total expenditures and the quantity of beef demanded. The results further revealed that the consumer demand for beef was negative and inelastic with respect to changes in beef price. Also, Baskhron et al. [20] examined the trends in the production and consumption of red and white meats in Egypt. The findings revealed a 1.40% and 2.87% annual growth rate in meat production and consumption respectively.Another study by Fatimah *et al*., [29] assessed the relationship between domestic consumption of red meat and its macroeconomics determinants in the Kingdom of Saudi Arabia. The results revealed a negative significant relationship between domestic consumption of red meat and meat price index; and a positive significant relationship with consumer price index in the long run. The results also portrayed a positive significant correlation between domestic consumption of red meat and GDP in the short run. In an attempt to understand the trend in meat production in Nigeria, Udom [38] analyzed trends for chicken meat, beef, goat meat (chevon), mutton and lamb, pig meat, and total meat from 1961 to 2004 period. With the exception of pig meat, annual growth rates derived from the exponential trend equations drastically declined from 4.50% during the 1961 – 1986 period to 2.26% during the 1986 – 2004 period. Also, Ojiako and Olayode [34] analyzed the livestock production trends from 1970 to 2005 in Nigeria. The results revealed an exponential growth rate of 4.83% per annum which assumes a significant acceleration in the long-run period.

As revealed from the reviewed literature, none of the research work has specifically focused on ruminant meat production despite the important role it plays in the dietary requirement of Nigerians. Therefore, the meat sub-sector needs specific policy recommendations to be able to tackle the current consumption deficiency gap in the

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country. Also, for the last two decades, a lot has happened in Nigeria's macroeconomic environment including the recent COVID 19 pandemic. Hence, there is a need to update the available information on the major meat trends and their relationships with key macroeconomic variables in the country. In line with this assertion, the study sought to examine the trends in the major ruminant meats in the country and establish the empirical correlations between key macroeconomic variables and ruminant meats production in Nigeria.

## MATERIALS AND METHODS

### Study Area

The study was conducted in Nigeria. The country is situated on the Gulf of Guinea in sub-Saharan Africa. It lies between $4^0$ and $14^0$ North of the equator and between longitude $3^0$ and $15^0$ East of Greenwich. Nigeria's land area is about 923,769km$^2$ and 853 km of coastline with a population of overtwo hundred (200) million [33]. The country has enormous agricultural, mineral, marine, and forest resources. The multiple vegetation, plenteous rain, surface water resources, and moderate climatic extremes, allow for the production of diverse foods, trees, and cash crops. Over 60 percent of the population is involved in the production of food crops such as cassava, maize, rice, yams, various beans and legumes, sorghum, ginger, onions, tomatoes, melons, and vegetables. Also, fishery, aquaculture and livestock production such as poultry, goat, sheep, pigs, and cattle flourished very well in all regions of the country. The main cash crops are cocoa, cotton, groundnuts, palm oil, and rubber [30].

### Data source

The study used secondary data sourced from the World Bank and Food and Agricultural Organization (FAO) as well as the Central Bank of Nigeria. Data used in the study covered the period from 1961 to 2021.

### Model Specification

To examine the trend in ruminant meat production in Nigeria:

An exponential trend equation was specified as presented in equation 1.

$$log_e MET_t = \varphi_0 + \varphi_1 T + U_t \dots\dots\dots\dots (1)$$

where 'T' is the time period measured in years. The exponential or compound growth rate is expressed as in equation 2.

$$(r) = (e^{\varphi_1} - 1) * 100 \dots\dots\dots\dots\dots\dots\dots (2)$$

To ascertain whether the growth in specific ruminant meat production assumes an accelerated or decelerated pattern during the period under consideration, a quadratic trend equation was specified as shown in equation 3:

$$log_e MET_t = \beta_o + \beta_1 T_1 + \beta_2 T_1^2 + u_t \dots\dots (3)$$

If the coefficient $\beta 2$ is positive and statistically significant at a conventional level, there is an annual acceleration in the growth of the ruminant meat; if the coefficient of $\beta 2$ is negative and statistically significant at the conventional level, there is a significant deceleration; however, if $\beta 2$ is not statistically significant it implies stagnation in the growth of ruminant meat production in the country [34, 7, 3].

### The determinants of ruminant meat

The relationship between annual meat production and macroeconomics variables was explicitly captured in a Cobb-Douglas form and is expressed as:

$$\mathrm{Meat_t} = \mathrm{f(INF_t, PCI_t, EXC_t, CRE_t)} \dots\dots (4)$$

where:

MET = Growth rate in total ruminant meat production (%) (either Beef, Mutton, Chevon, orcombined)

$PCI_t$ = Growth rate in the per capita income as a proxy of demand capacity (i.e. per capita GDP) (%)

$INF_t$ = Growth rate in the annual inflation rate as a proxy of meat price (%)

$EXC_t$ = Growth rate in the annual exchange rate as a proxy of import effect (naira/dollar) (%)

CREt = Growth rate in annual domestic credit to agriculture/GDP as a proxy of infrastructuralavailability (%).

An implicit autoregressive version of equation 4 was specified and is expressed as shown:

$$MET_t = \beta_0 + \ +\delta_1 PCI_t + \delta_2 INF_t + \delta_3 EXC_t + \delta_4 CRE_t + \delta_5 MET_{t-1} + U_t \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Equation 5 was adopted in the study to solve the problem of autocorrelation that existed in equation 4. The variables were expressed in growth rates to ensure their stabilities at the level of the variables and reduce the tendency of producing a spurious regression.

## RESULTS AND DISCUSSIONS

The results in Table 1 show the major descriptive statistics of the variables used in the study. The coefficients of variability in beef, chevon, and mutton were 27.14%, 73.22%, and 79.56% respectively. This implies that there was minimal variation in the annual tonnage of beef, while chevon and mutton production witnessed significant fluctuations in production over the specified period. The indices of skewness (being positive) revealed that the production of the individual ruminant meat in the country grew steadily as they concentrated more on the right-hand side of the normal distribution curve. However, the statistic for the combined meats (beef, mutton, and chevon) indicates an average coefficient of variability at 43.74% per annum and negative skewness. The result revealed that the combined ruminant meat production (or total ruminant meat) had moderate variability characterized by a marginal decline in annual production. The descriptive statistics of the macroeconomic variables showed explosive variabilities in per capita income (PCI) and exchange rate (EXC). This implies that these variables were so unstable during the period specified in the study.

Table 1. The Descriptive Tests of Variables Used in the Estimated Models

| Variable | Mean | Minimum | Maximum | Std. dev. | CV | Skewness |
|---|---|---|---|---|---|---|
| Beef (tons) | 2.7396e+005 | 1.4624e+005 | 4.3772e+005 | 74353. | 0.2714 | 0.0964 |
| Chevon (tons) | 1.3779e+005 | 5715.0 | 2.8766e+005 | 1.009e+005 | 0.7322 | 0.0711 |
| Mutton (tons) | 72540. | 6820.0 | 1.7160e+005 | 57711 | 0.7956 | 0.3453 |
| INF | 16.160 | 0.47606 | 72.836 | 14.975 | 0.9267 | 2.0959 |
| PCI | 1.4062e+005 | 69.272 | 7.4829e+005 | 2.262e+005 | 1.6085 | 1.5160 |
| EXC | 72.924 | 0.54678 | 403.58 | 103.33 | 1.4169 | 1.4855 |
| CRE | 8.5579 | 3.7043 | 19.626 | 3.2404 | 0.3787 | 1.3268 |
| Total meat (tons) | 4.8429e+005 | 1.5974e+005 | 7.7806e+005 | 2.119e+005 | 0.4374 | -0.0810 |

Source: The tests are computed by the author's data from the FAO [23- 28] and World Bank, 2022 [40].

The inflation rate also showed a high degree of variability of about 92.67% per annum. The coefficient of variability was lowest in the amount of credit disbursed to the agricultural sector. This implies that the amount of credit allotted to the agricultural sector over the years skewed positively but did not change significantly. The skewness indices for the macroeconomic variables were positive and imply that their volatilities and annual production were progressive or continuous over the period considered.

**The Trend in ruminant meats production in Nigeria**

The estimates of the exponential and quadratic trend equations for beef and chevon production are presented in Table 2, while Table 3 contains estimates for the mutton and combined meat (beef, chevon, and mutton) production. The findings revealed that the beef and chevon production in Nigeria has apositive significant relationship with time. This implies that beef and chevon annual production increases on average over time within the period used in the study. An average positive exponential growth rate of about 1.16% and 6.69% per year were obtained in beef and chevon production from 1961 to 2021 respectively in Nigeria.

Table 2. The exponential and quadratic trend estimates of beef and chevon production in Nigeria

| | Beef | | | Chevon | | |
|---|---|---|---|---|---|---|
| **Equation 1** | **Exponential Trend Equation** | | | | | |
| Variable | Coefficient | Std. error | t-value | Coefficient | Std. error | t-value |
| Constant | 12.1245 | 0.0812 | 149.4*** | 9.3218 | 0.2019 | 46.18*** |
| Time | 0.0115 | 0.0017 | 6.875*** | 0.0648 | 0.0059 | 10.96*** |
| R-square | 0.51 | | | 0.88 | | |
| F- cal. (1, 59) | 47.26*** | | | 120.12*** | | |
| Exp. GR (%) | **1.156** | | | **6.694** | | |
| | | | | | | |
| **Equation 3** | **Quadratic trend Equation estimates** | | | | | |
| Variable | Coefficient | Std. error | t-value | Coefficient | Std. error | t-value |
| Constant | 11.9322 | 0.0479 | 249.3*** | 8.3657 | 0.0452 | 185.0*** |
| Time | 0.0299 | 0.0070 | 4.261*** | 0.1559 | 0.0030 | 51.29*** |
| Time Square | −0.0003 | 0.0001 | −2.456** | −0.0015 | 4.798e-05 | −30.61*** |
| R-squared | 0.60 | | | 0.69 | | |
| F- cal.(2, 58) | 106.64*** | | | 29.12*** | | |

Source: computed by the author.

Note: ***, ** and * indicate 1%, 5% and 1% significance levels respectively.

The quadratic trend estimates for beef and chevon revealed for each equation respectively, a time-squared coefficient that is negative and statistically significant at the conventional probability levels. This implies that theproduction of beef and chevon over an increased period of time experienced deteriorating growth rates in annual production in the country. The results indicated a significant deceleration in annual growth of outputs of beef and chevon over an increased period of time. Though the compound growth rates for beef and chevon revealed a positive annual growth rate, the estimates of the quadratic trend equation showed an unsustainable annual growth rate in production. Alternatively, the result of the quadratic trend equation revealed that the exponential or compound growth rate of beef and chevon grew positively at a decreasing rate in the long-run period. This implies that several policies and programs that were implemented by the various tiers of governments to boost beef and chevon production in the country yielded significant short-run positive impacts that seem to depreciate in the long run.

Similarly, the result for mutton and combined meat (beef, chevon, mutton) production revealed a positive significant relationship with the time coefficient. This implies that mutton and total ruminant meat annual production increase on average with time. Precisely, an average positive exponential growth rate of about 6.03% and 2.75% per annum were obtained in mutton and aggregate ruminant meat production from 1961 to 2021 respectively in Nigeria. Further investigation on the nature of the exponential growth in mutton and total meat revealed significant deceleration over an extended period of time. This implies that the exponential growth rate in mutton and combined ruminant meat production was increasing at a decreasing rate. Following the history of Nigeria's economy, many phenomena could likely help to explain the short and long period trends in major ruminant meats production in Nigeria. Similar studies have estimated a single-digit exponential growth rate for agricultural commodities. They include; Udom [39]; Ojiako and Olayode [34], andBaskhron et al. [20].

The pictorial representation of the estimated trend lines for beef, mutton, chevon, and combined ruminant meat annual production is shown in Figure 2. The trend in meat production assumed an upward progressive growth from 1961 to 1985. This period corresponds to the era of the pre-structural adjustment programme (SAP).

Table 3. The exponential and quadratic trend estimates of mutton and combined ruminant meat production in Nigeria

| | Mutton | | | Combined (beef, chevon and mutton) | | |
|---|---|---|---|---|---|---|
| **Equation 1** | **Exponential Trend Equation** | | | | | |
| Variable | Coefficient | Std. error | t-value | Coefficient | Std. error | t-value |
| Constant | 8.9228 | 0.0809 | 110.2*** | 12.1332 | 0.0714 | 169.9*** |
| Time | 0.0586 | 0.0032 | 18.25*** | 0.0271 | 0.0019 | 14.28*** |
| R-square | 0.95 | | | 0.88 | | |
| F- cal. (1, 59) | 33.00*** | | | 23.97*** | | |
| Exp. GR (%) | **6.032** | | | **2.747** | | |
| | | | | | | |
| **Equation 3** | **Quadratic trend Equation estimates** | | | | | |
| Variable | Coefficient | Std. error | t-value | Coefficient | Std. error | t-value |
| Constant | 8.5074 | 0.0901 | 94.38*** | 11.8750 | 0.0456 | 260.7*** |
| Time | 0.0981 | 0.0073 | 13.41*** | 0.0517 | 0.0053 | 9.676*** |
| Time Square | −0.0006 | 0.0001 | −5.73*** | −0.0004 | 8.847e-05 | −4.482*** |
| R-squared | 0.68 | | | 0.63 | | |
| F- cal.(2, 58) | 64.39*** | | | 60.57*** | | |

Source: computed by the author.
Note: *** indicates 1% significance level.

The agricultural policies and programmes then were majorly targeted at the development of the agricultural sector at the regional levels. For instance, in1962 in northern Nigeria, there was a supplementary feed programme on cattle aimed at increasing the quality of beef produced [30].

In 1965, grazing reserves were introduced in the northern region to improve the quality of feeds and meat correspondingly. In 1979, a smallholder fattening scheme was initiated as a tool to increase ruminant farmers' income through an increase in quality meats [30].

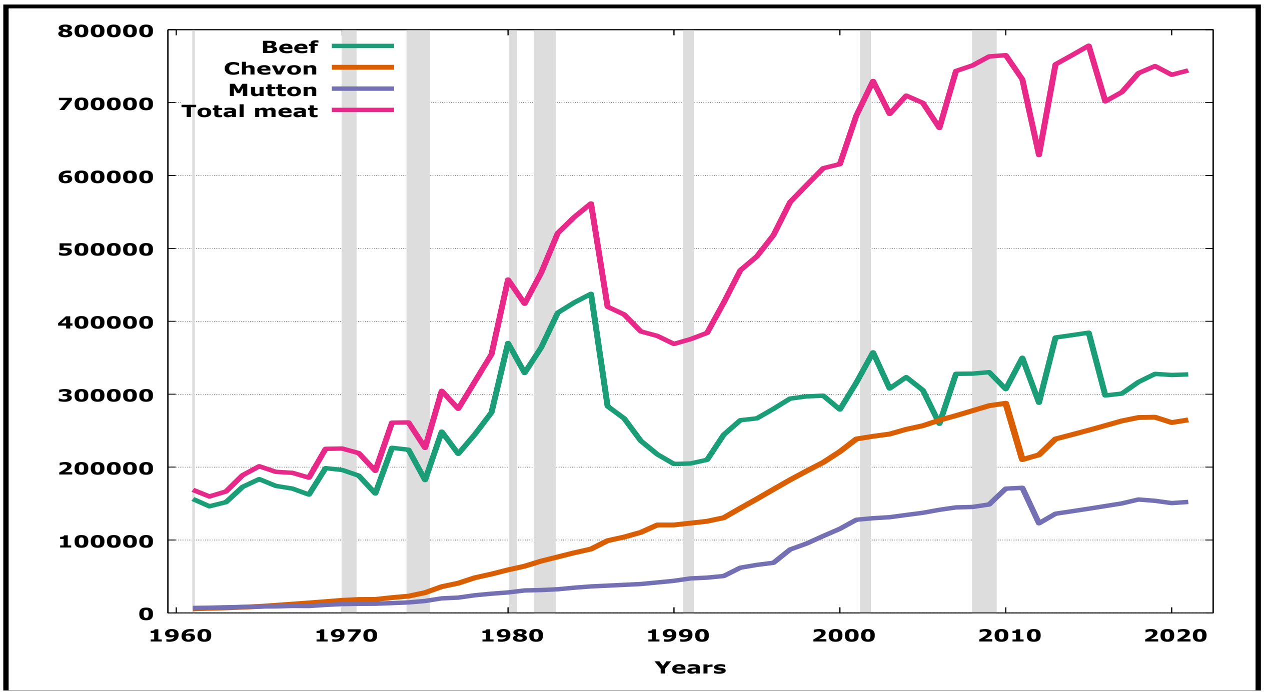


Fig. 3. Trends in Beef, Chevon, Mutton and Combined Meat (tons) in Nigeria.
Source: Plotted by authors and data from FAO [23-28].

Within this period, trade policies were instituted to protect domestic ruminant meat producers. From 1971 and 1973, the beef import was banned while supplementary feeding programmes for livestock which served as incentives continued from 1971 to 1974 in the country [39]. The Nigerian Livestock Production Company (NLPC) was established in 1976 to provide credit and technical services to farmers. Ruminant meat producers within the period had several incentives to leverage, and these resulted in the corresponding increase in meat production in this era.

The trend in ruminant meat production witnessed a sharp depression from 1986 to 1993. The trend in beef, mutton and chevon production in this period was mainly dictated by the policies and programs of the structural adjustment program era.

The remarkable characteristic of this era was the privatization and commercialization of government-owned agro-enterprises. During this time, private investment in meat production witnessed a remarkable increase, but improvement in the sub-sector was hampered by increasing volatility in the macroeconomic fundamentals. In 1988, a ban on imports of fresh, chilled, or frozen meat was enforced to protect domestic producers, but the intention was defeated due to an unfavourable macroeconomic environment.

The post-SAP era which spanned from 1993 to 2021 saw the introduction of new agricultural policies including a ban on the importation of frozen poultry meat, the national currency was devaluated and private roles in meat production, processing and marketing increased tremendously. These and several incentives upsurge meat production although in undulating pattern until 2020 when COVID-19 pandemic and persistent increase in feed prices stalled the production capacity of meat producers and resulted in a reduction in annual output.

**Unit root test**

To test the stability of the variables used in the study, the ADF-GLS test was used to confirm the unit root of the specified variables. The results are presented in Table 4. The findings revealed that all the specified variables were stationary at their levels. This denotes that the specified regression model can be estimated at the level of these variables with little or no risk of obtaining spurious estimates.

Table 4. ADF-GLS unit root tests

| Variables | ADF-GLS (constant and trend) | | |
|---|---|---|---|
| | **Level** | **1st Diff.** | **Decision** |
| Total meat (tons) | -9.3369*** | – | 1(0) |
| INF | -7.6647*** | – | 1(0) |
| PCI | -6.5589*** | – | 1(0) |
| EXC | -8.5682*** | – | 1(0) |
| CRE | -8.3414*** | – | 1(0) |

Source: computed by the author.
Note: ***, ** and * indicate 1%, 5% and 1% significance levels respectively. Note that, variables were expressed as natural logarithm growth rate.

**Determinants of ruminant meats production in Nigeria**

The result in Table 5 presents the estimates of the autoregressive models for the beef equation while Table 7 contains the estimates for chevon and total ruminant equations. The R-squared is estimated at 0.19 and 0.39 for beef and chevon respectively. The F- statistics of 9.01 and 22.47 are significant at the conventional probability levels for the beef and chevon equation respectively. This means that the estimated R-squared for both equations are significant and thus indicate that both equations have goodness of fits. The estimated value of Durbin-Watson which is 2.19 for the beef equation and 2.33 for chevon were not statistically significant, implying that there is an absence of serious autocorrelation in the estimated equations. Also, the null hypotheses were not rejected for the RESET test, Breusch-Pagan test, normality test, and CUSUM test for both equations. This means that the estimated autoregressive models have structural rigidity, absent of heteroscedasticity, normally distributed error terms and is stable within the time frame specified.

Table 5. Determinants of Beef and Chevon production in Nigeria

| Variables | Beef estimates | | | | Variables | Chevon estimates | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | Std. error | t-value | VIF | | Coeff. | Std. error | t-value | |
| Constant | 0.079 | 0.1564 | 0.509 | - | Constant | 0.171 | 0.1096 | 1.564 | - |
| Inflation | −0.001 | 0.0005 | −2.065** | 1.017 | Inflation | −0.0004 | 0.0002 | −2.000** | 1.078 |
| Per capita income | 0.028 | 0.0122 | 2.295** | 1.544 | Per capita income | 0.035 | 0.0194 | 1.804* | 1.431 |
| Exchange rate | 0.005 | 0.0009 | 5.019*** | 1.052 | Exchange rate | −0.0008 | 0.0002 | −3.468*** | 1.026 |
| Credit to Agric. | 0.008 | 0.0179 | 0.421 | 1.386 | Credit to Agric. | 0.016 | 0.0116 | 1.410 | 1.408 |
| Beef lag 1 | −0.198 | 0.1777 | −1.116 | 1.192 | Chevon lag 1 | 0.534 | 0.1731 | 3.086*** | 1.108 |
| | | | | | | | | | |
| R-squared | 0.1917 | | | | R-squared | 0.3884 | | | |
| F- cal. (5,53) | 9.0122 (0.0011) | | | | F- cal. (5,53) | 22.4663 (0.0000) | | | |
| Normality test | 0.8039 (0.6690) | | | | Normality test | 2.1283 (0.3132) | | | |
| RESET test | 1.3333 (0.1436) | | | | RESET test | 1.5450 (0.1064) | | | |
| Breush-Pagan | 8.3285 (0.1967) | | | | Breush-Pagan | 4.3444 (0.3014) | | | |
| CUSUM test | 0.2527(0.8015) | | | | CUSUM test | 2.1254 (0.3833) | | | |
| Durbin Watson | 2.1855 (0.7608) | | | | Durbin Watson | 2.3329 (0.8842) | | | |

Source: computed by the author.
Note: ***, ** and * indicate 1%, 5% and 1% significance levels respectively. Note that, variables are expressed in a natural logarithm.

The diagnostic statistics for the mutton and combined ruminant meat equations are presented in Table 6. The R-squared are 0.11 and 0.18 for mutton and combined meat equation respectively. The F- statistics for both equations are significant at the conventional probability levels and thus indicate the goodness of fit. The Durbin-Watson values of 2.06 for the mutton equation and 2.18 for combined meat were statistically insignificant, implying no serious autocorrelation in the estimated equations. Similarly, the null hypotheses were not rejected for the RESET test, Breusch-Pagan test, normality test, and CUSUM test for both equations.

**Determinants of Beef production in Nigeria**

The empirical result revealed that the price of beef (proxy by inflation growth rate) has a significant negative inelastic relationship with beef production in Nigeria. A one percent increase in inflation growth rate will cause about a 0.001% decrease in the growth rate of beef production in Nigeria. This means that as the inflation rate upsurge, the quantity of beef produced in the country declines. The result satisfies a priori expectation as the soaring inflation rate has a negative multiplier effect on all sectors of the economy such as transportation, cost of raw materials, and marketing cost among others, resulting in an increase in production cost. An increase in production cost reduces the producer's profit through a reduction in the quantity of goods produced. The result corroborates Simo-Kengne*et al.,* [36], Akpan *et al.,* [14], Akpan et al., [11], James et al., [31], and Fatimah et al., [29].

The result also shows a positive relationship between the per capita income and the quantity of beef produced in the country. For instance, a unit increase in the per capita income would likely result in about a 0.028 unit increase in beef production in the country. An increase in per capita income suggests an increase in the consumers' income (on the assumption that the per capita income is not significantly skewed). This means that as the per capita income increases, both the nominal and the real income of an average consumer will increase thus enhancing the consumer's purchasing power. The finding agrees with the reports of Akpan et al., [17]; Akpan and Patrick [4], FAO, [27], FAO, [23], and FAO, [28], Akpan *et al.,* [14], Akpan et al., [11], Akpan and Umoren [9] and Betru and Kawashima [21].

Similarly, the result revealed a positive inelastic correlation between the nominal exchange rate (i.e. naira/dollar) and beef production capacity in Nigeria. By implication, a unit increase in the annual nominal exchange rate would lead to a 0.005 unit increase in beef production in Nigeria.

Table 6. Determinants of mutton and combined meat production in Nigeria

| Variables | Mutton | | | | Variables | Combined meat | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | Std. error | t-value | VIF | | Coeff. | Std. error | t-value | |
| Constant | 0.303 | 0.1024 | 2.957*** | - | Constant | 0.183 | 0.1204 | 1.517 | - |
| Inflation | −0.0008 | 0.0004 | −2.124** | 1.009 | Inflation | −0.0009 | 0.0004 | −2.104** | 1.023 |
| Per capita income | 0.072 | 0.0273 | 2.632** | 1.493 | Per capita income | 0.028 | 0.0144 | 1.944* | 1.645 |
| Exchange rate | 0.0004 | 0.0002 | 1.510 | 1.025 | Exchange rate | 0.003 | 0.0007 | 4.834*** | 1.053 |
| Credit to Agric. | 0.015 | 0.0109 | 1.335 | 1.414 | Credit to Agric. | 0.005 | 0.0119 | 0.419 | 1.387 |
| Mutton lag 1 | 0.053 | 0.0893 | 0.5915 | 1.093 | Total meat lag 1 | −0.192 | 0.1941 | −0.991 | 1.289 |
| | | | | | | | | | |
| R-squared | 0.1069 | | | | R-squared | 0.1813 | | | |
| F- cal. (5,53) | 5.3690 | | | | F- cal. (5,53) | 9.5682 | | | |
| Normality test | 1.3723 (0.4045) | | | | Normality test | 2.7799 (0.1916) | | | |
| RESET test | 1.0232 (0.5744) | | | | RESET test | 1.4965 ( 0.1924) | | | |
| Breush-Pagan | 4.7755 (0.3194) | | | | Breush-Pagan | 4.7636 (0.3155) | | | |
| CUSUM test | -1.2642 (0.2118) | | | | CUSUM test | 0.1129 (0.9106) | | | |
| Durbin Watson | 2.0568 (0.5704) | | | | Durbin Watson | 2.1807(0.7529) | | | |

Source: computed by the author.

Note: ***, ** and * indicate 1%, 5% and 1% significance levels respectively. Note that, variables are expressed in a natural logarithm.

An increase in the nominal exchange rate (naira against the dollar) will likely constrict the importation of meat-related products thereby promoting the domestic production of meats. Akpan *et al.,* [14], and Akpan and Umoren [9] have reported similar results.

**Determinants of chevon production in Nigeria**

The determinants of chevon production are similar to beef production. The empirical results revealed that an increase in the annual inflation rate has a significant adverse inelastic relationship with chevon production. The finding connotes that a unit increase in the annual inflation rate will trigger a 0.0004 unit decrease in the annual chevon production. The result is buttressed by the submissions of Simo-Kengne*et al.,* [36], Akpan *et al.,* [14], Akpan et al., [11], James et al., [31], and Fatimah et al., [29].

Correspondingly, the annual nominal exchange rate correlates negatively to chevon production in Nigeria. Precisely, a unit increase in the nominal exchange rate (naira against the dollar) would likely reduce chevon production by 0.0008 units. The occurrence of this relationship could be linked to the fact that a good proportion of goats slaughtered in Nigeria are imported from neighbouring countries like; Niger, Cameroun, Chad, and Sudan. The country depends heavily on imported goats for the domestic chevon market. Therefore, an increase in the nominal exchange rate (i.e. naira /dollar) would likely increase the cost of importation in the local currency thus resulting in a reduction in the number of goats imported. The reduction in the number of goats imported would likely have a diminishing impact on the quantity of chevon or goat meat supply in the domestic market. Similar reports are presented by Akpan *et al.,* [14], and Akpan and Umoren [9].

Contrary, the coefficient of the per capita income has a significant positive inelastic association with the chevon production in Nigeria. For instance, a 10.0% increase in the per capita income would lead to a 0.35% increase in chevon production. The plausible reasons for the results obtained for beef production are also applied for chevon production. Akpan et al., [17]; Akpan and Patrick [4], FAO, [27], FAO, [23], FAO, [28], and Betru and Kawashima [21] agree with the finding.

**Determinants of mutton production in Nigeria**

The result indicates that the inflation rate (or the market price) has a significant inelastic negative correlation with the annual production of mutton in Nigeria. Following the law of demand, an increase in the price of a normal commodity has a negative impact on demand. The result showed that a 10.0% increase in the inflation rate will induce about a 0.008% reduction in the production of mutton. The finding is substantiated by Simo-Kengne *et al.,* [36], Akpan *et al.,* [14], Akpan et al., [11], James et al., [31], and Fatimah et al., [29].

On the opposing side, the slope coefficient of per capita income is positive at a 5.0% probability level indicating a significant positive relationship with mutton production in Nigeria. For instance, a unit increase in the per capita income will cause about a 0.072 unit increase in mutton production. The finding agrees with the reports of Akpan et al., [17]; Akpan and Patrick [4], FAO, [27], FAO, [23], and FAO, [28], Akpan *et al.*, [14], Akpan et al., [11], Akpan and Umoren [9] and Betru and Kawashima [21].

**Determinants of total ruminant meat production in Nigeria**

The empirical results indicate that the combined ruminant meat (that is, consisting of beef, chevon, and mutton) has a significant negative inelastic relationship with the annual inflation rate and a significant positive inelastic correlation with the per capita income and nominal exchange rate. The following empirical researches support the finding: Simo-Kengne *et al.,* [36], Akpan *et al.,* [14], Akpan et al., [11], James et al., [31],and Fatimah et al., [29], FAO, [27], FAO, [23], and FAO, [28], Akpan and Umoren [9], and Betru and Kawashima [21].

## CONCLUSIONS

Ruminant meats constitute more than 50% of the total meat consumption in the country and it is a key component of the livestock system. From the available data, Nigeria is not self-sufficient in animal protein production and consumption. It is obvious that the rate of annual growth in ruminant meat production is insufficient to meet the minimum World Health Organization animal protein requirement in the country. To upsurge animal protein production and consumption in the country, key macroeconomic variables have to be stabilized in addition to other prerequisites.

The study estimated 1.156%, 6.694%, 6.032%, and 2.747% annual exponential or compound growth rates in beef, chevon, mutton, and combined ruminant meats production respectively in Nigeria. In addition, the study establish that changes in the annual inflation rate, per capita income (GDP), and nominal exchange rate were statistically significant in influencing ruminant meats production in the country.

Based on these findings, it is recommended that the country should moderate the rate of annual inflation, improve the per capita income and ensure a favourable exchange rate.

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# SUSTAINING THE GROWTH OF SMALL-SCALE FARMING: EVIDENCE FROM THE GROSS MARGINS OF SMALL–SCALE CASSAVA FARMERS IN UYO AGRICULTURAL ZONE, AKWA IBOM STATE, NIGERIA

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***Abstract***

*Cassava production in the Southern region of Nigeria is seen as one of the prominent cultural practices of the natives. The potentials of cassava derivatives and their value chains are enormous in reducing poverty and triggering economic development in the region. Premised on these assertions, the study was designed to analyze the gross margins of cassava farmers and determine factors that affect it in the southern region of Nigeria. In the study, 120 cassava farmers were randomly sampled using structured questionnaire. The descriptive analyses of the data collected revealed that women dominated cassava production in the region. The farmers were moderately educated with an average farming experience of 11.9 years, and average social capital accumulation, age, farm income, gross margin, and farm size of 6.0 years, 44.3 years, ₦68, 694.17, ₦29, 793. 57 and 0.59 hectares respectively. The empirical findings revealed that farmers' age, education, farming experience, social capital, cassava cutting, and farm size were significant positive determinants of cassava farmers' gross margins while household size, transaction cost and access to farm credit relate negatively. Based on the findings, it is recommended that youth should be encouraged in cassava production as a way to augment the aging cassava population in the region. Also, adult education should be encouraged among cassava farmers in addition to promoting moderate household size among others.*

***Key words*: *gross margin, cassava, small-scale, farmers, Nigeria***

## INTRODUCTION

Cassava (*Manihot esculenta*) is one of the most popular food crops grown in the southern part of Nigeria [19, 14, 38, 41]. The crop is one of the widely consumed root crops in the country. Cassava production not only serves as a good source of food crop but also a major source of income and employment for rural dwellers in Nigeria [26, 38, 4]. Based on its wide acceptability, the crop is considered a very powerful weapon against poverty in Nigeria [28]. The crop is considered one of the most productive and sustainable crops in the Tropics [37]. Apart from its productivity and dogged nature, the crop is easily adaptable to various soil types, soil fertility levels, and climatic conditions. Nigeria is the largest producer of cassava in the world, however, the current yield of 8.2MT/ha, as opposed to a potential of 20-30MT/ha, indicates that there exists inefficiency in cassava production and technology used compared to the world's best practices [27, 33]. According to Akpan et al., [14], the crop can be processed into several derivatives such as: garri, starch, fufu, cassava flour, and cassava chips among others. Cassava tubers have excellent potential in livestock feed formulation, textile industry, plywood, paper, brewing, chemicals, pharmaceutical, and bakery industries [40, 2]. Resulting from the critical roles cassava production offered to Nigeria's economy, the government at all tiers has enunciated and set up several policies and programmes to boost its production in order to meet the rising demand for the commodity [24].

Following these interventions initiated by the government, cassava production in the southern region of Nigeria is still characterized by small-scale production, largely subsistent, utilized obsolete tools, poor varieties, and is affected by uncertainties of rain as well as other exogenous constraints inherent in arable crop production [13, 14].

Several aspects of the crop agronomical activities are still done with crude or traditional tools. According to Udoh and Akpan [43], and Akpan [6, 7] most small-scale farmers are resource poor in Nigeria. With rampaging general poverty and double digits inflation rate as well as insufficient credit facilities for the agricultural sector; farm productivity and farm income are seriously jeopardized in the country [44]. Additionally, with the increasing rural-urban migration among youths in the southern region of Nigeria [17, 18, 3], the relative scarcity of rural labour constitutes a serious impediment to small-scale farmers in the region [5, 31]. In a nutshell, a small-scale farmer in the region is mostly challenged by uncertainties in farm productivity, farm output, farm income, and gross margins including high level of macroeconomic volatility [11, 10]. The extent an individual farmer is able to cope with the cultural, environmental, climatic, and economic constraints in production in addition to the level of resource endowment and technology determined the level of investment in farm production [43].

Cassava production in the southern region of Nigeria has continued to suffer severe setbacks due to various factors ranging from continuous cropping emanated from land fragmentation, high population density, high cost of inputs, and soil deterioration thereby hindering most farmers to attain the optimum level of production [32, 17]. The inability of farmers to adequately address these issues has resulted in sub-optimal use of resources, substantial loss of cassava output, and a drastic reduction in profit/gross margins accruable to farmers [15, 20]. This connotes that, the sustainability of small-scale farm enterprise is hinged on tackling the issue of resource allocation problem with the aim of maximizing farm returns. From another perspective, the issue of deteriorating farmers' welfare in developing economies is alarming. Yet it is these farmers' that produced almost 90% of farm products meant for consumption in the region. Several submissions have shown that more than 50% of the rural farmers live below the national poverty line and are resource-poor [29, 36, 9, 12, 43, 22]. Given this report; it is pertinent to investigate and document the nature of cassava gross margins, and the factors that influence it in the southern region of Nigeria.

The reasons for the above assertions are obvious; first, the cassava sub-sector provides numerous employment opportunities to people through its value chain activities in the country. Secondly, it serves as a valuable source of dietary energy for the majority of people in Nigeria, particularly in the southern part of the country. For instance, 80% of the cassava tubers produced in Nigeria are processed into various food products that are consumed locally, and minimum quantities are exported to neighboring African countries [24, 21, 14]. Given that cassava is an important staple food in the region and the country at large, any attempt to increase its production and the farmer's productivity would be the right step toward preventing food crises in the country.

In the southern region of the country, especially in Akwa Ibom State, bold steps have been taken to tap the potential of cassava through its cassava competitiveness initiative. As a result, some bakeries adopted the use of 10% cassava flour in the contents of their bread. The Akwa Ibom State government also participated in Fadama III additional financing which targeted majorly cassava production [42]. Also, Fadama micro-finance Bank was established in the State for soft loans for small-scale farmers in the State among others. In spite of the government's good intentions regarding cassava production in the State, especially in creating a favourable production environment, the performance of the State as regards increased cassava production as a major revenue earner has still not reached its full potential. Furthermore, it is essential to understand the socio-economic and demographic factors that played leading roles in the production process of cassava in order to achieve maximum outputs and profit in the State. The generation of such information is critical in developing long-term research policies and in understanding the subsistence farming situation. Therefore, based on the aforementioned problems, this study sort to analyze the gross margin of cassava farmers and identify factors affecting it in the southern region of Nigeria.

However, there are few studies that examined the gross margins of arable crop farmers in developing countries. For instance, Ridwan *et al.* [39] examined the determinants of the gross margin of the vegetable farmers in the Iwo zone of Osun State of Agricultural Development Programme (ASDP). The result of the findings revealed that the labour cost, cost of fertilizer, and cost of seed were the main determinants of the gross margin in vegetable production. Also, Akpan et al., [16] analyzed the gross margins of manure and fertilizer-based waterleaf (*talinum triangulare*) farmers in Nigeria. The empirical results showed that farmers' education, farm income, and gender had a significant positive impact on the gross margin of organic manure users while stem cost, household size, membership in social organization, labour cost, and farm credit showed a significant negative effect. Also, farmers' age, farm income, and household size showed a positive effect on the gross margin of fertilizer-based farmers while education, marital status, stem cost, social organization, labour cost, the quantity of Waterleaf stolen, gender, and farm size showed a significant negative impact. Besides, household size, household dependent ratio, and marital status have a negative impact. Furthermore, Mersha, et al., [30] identified factors affecting potato farmers' marketing gross margin in central Ethiopia. The empirical results showed that the educational level of household head, household size, potato cultivated land size, quantity of potato produced, input cost, livestock ownership, and access to market information had a significant effect on farmers' household gross margin. In addition, Abebe et al., [1] analyzed factors that affect the profitability of smallholder common bean producers in the central rift valley of Ethiopia. The empirical results showed that distance from the nearest market, farmers' age, family size, off-farm income, and fertilizer source were the factors that influenced the profitability of smallholder common bean producers negatively; whereas, gender; farming experience, group membership, and target market channel had a positive significant influence. In a similar vein, Ehinmowo et al., [25] analyzed the determinants of profitability among small-scale cassava processors in Southwest, Nigeria. The empirical results indicated that education, year of experience, access to extension services, household size, cost of raw materials, and types of cassava purchased were the factors that significantly determined profitability among cassava farmers. Oladoyin et al., [35] studied the economic analysis of cassava production in the Akoko area of Ondo State, Nigeria. The results showed that the majority (72.7%) of cassava farmers were male and were within the mean age of 50 years; have a mean household size of 5 persons. The majority of the farmers are married and had an average farming experience of 13 years while about 82.0% of the farmers had formal education. The cassava farmers had an average farm size of 1.9ha. The empirical result showed that agrochemical, labour, farm input, and age have a significant influence on the profit of the cassava farmers. Oladeebo and Oluwaranti's [34] reported that household size and farm size were the major significant factors that influenced the profit efficiency of cassava farmers. Akpan et al., [13] estimated farm-level profit function and its determinants among homestead-based cassava farmers in the south-south region of Nigeria. The result found that farmers' education, experience, household size, level of farming involvement, extension agent visit, soil management method adopted by farmers, and farm size were significant factors affecting farm-level profit efficiency. Akpan et al., [19] estimated translog stochastic profit function for cassava-based farmers in the southern wetland region of Cross River State, Nigeria. The findings showed that level of farming involvement, farmer's education, ability to predict rainfall, farming experience, household size, soil management technique adopted, extension agent visits, and farm size were significant determinants of profit efficiency of cassava-based farmers. Akpan et al., [8] used a stochastic production frontier function to estimate farm-level technical efficiency and its determinants among cassava-based farmers in Oruk Anam Local Government Area of Akwa Ibom State, Nigeria. The descriptive analysis of cassava farmers revealed an average age of 45 years, and household size of 6 members. About 68% of cassava farmers were poor, while farmers' average years of social capital formation and education stood at 1.08 years and 9 years respectively. The empirical results showed that, farmers' farming experience and membership in social organization were positive drivers of technical efficiency among cassava farmers in the State. Alternatively, farmers' age, household size, gender, and poverty status were identified as negative movers of the technical efficiency of cassava farmers.

From the literature review, it is clear that there is an overwhelming need to update available information on the gross margins of small-scale farmers in the southern region of Nigeria. Again, given the critical role cassava production plays in the self-food sufficiency program of the federal government and the southern region of the country in particular, it is pertinent to analyze the gross margin of farmers being one of the indicators of agricultural sustainability.

## MATERIALS AND METHODS

### Area of study

The study was conducted in Uyo agricultural zone in Akwa Ibom State in the southern region of Nigeria. The State has six agricultural zones namely: Uyo, Oron, Eket, Ikot Ekpene, Etinan, and Abak. Uyo Agricultural zone consists of the following local government areas; Uyo, Ibesikpo Asutan, Itu, Uruan and Ibiono Ibom Local Government Areas [16]. The average rainfall in the Uyo zone ranges from 2,000mm and 3,000mm per annum. Uyo has two identifiable seasons; which are the rainy and dry seasons. The average annual temperature and relative humidity in Uyo agricultural zone range from 26°C to 27°C and 75% to 95% respectively. The zone is blessed with abundant mineral resources including gravel, silica sand, clay etc. Crops widely grown in the zone are cassava, leafy vegetables such as waterleaf, fluted pumpkin, and garden egg. Others include maize, yam, pepper, plantain, and cucumber. Some households grow cash crops such as oil palm, rubber, and cocoa [16].

**Sources of data and instrument for data collection**

Primary data consisting of socio-economic features, production and marketing data among others was used in this study. A well-developed structured questionnaire was used to elicit information from the respondents. The respondents were cassava farmers who practiced either sole or mixed cropping system.

Personal interview of the key informants was also conducted to ensure the consistency and accuracy of the data collected.

**Sample size selection**

Following Cochran [23], a representative sample size from a large population of cassava farmers in the Uyo agricultural zone was obtained using the equation (1) specified as thus:

$$S_n = \frac{z^2\rho(1-\rho)}{D^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where: $S_n$ is the required sample size from a large population; "Z" is the standard normal variate (at 95% confidence interval, type 1 error; 1.96). "P" is the expected proportion of cassava farmers in the population (From the record of the Akwa Ibom State Agricultural Development Programme "AKADEP" about 92% of farmers in the Uyo agricultural zone cultivate cassava either as full-time or part-time farmers). "D" is the absolute error or precision at 5% type 1 error. The sample size is derived as shown in equation 2.

$$S_n = \frac{(1.96)^2 0.92(1-0.08)}{(0.05)^2} = 113 \ldots.(2)$$

To obtain a more representative and proportional sample among selected villages, the sample size was increased to one hundred and twenty (120) cassava farmers.

**Sampling procedure and sample size**

The first procedure was the use of simple random sampling method to select three LGAs from the six LGAs that constitute the

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Uyo agricultural zone. The selected LGAs are Itu, Uyo and Ibesikpo. The second stage involved the use of simple random sampling method to select five villages from each of the previously selected three LGAs. In the selection of the villages, emphasis was given to those villages noted for intensive production of cassava. A total of 15 villages from three local government areas were selected and used for data collection. In the third stage, the simple random sampling method was used to select eight (8) cassava farmers from each of the fifteen villages. A grand total of one hundred and twenty (120) cassava farmers (forty (40) from each of the three LGAs) were selected and used in the study.

**Analytical Techniques**

**The determination of the gross margin of Cassava farmers**

The gross margin estimated for smallholder cassava farmers is defined as follows:

GM = Total Revenue – Total variable Cost…. (3)

The total revenue consisted of annual revenue (i.e. Revenue for one full production cycle) from cassava tubers and stem sales. The total variable cost consisted of annual costs of labour, weeding, manure/fertilizer, land clearing, planting materials as well as transportation cost. The estimation of the gross margin serves as a profit index for cassava farmers. As it is conventional, the higher the Gross margin, the more profitable a farm is likely to be, and the smaller the Gross margin, the lesser the profitability.

**Determination of factors affecting the gross margin of small – scale Cassava farmers**

A multivariate regression model based on the Ordinary Least Squares estimation method was used to determine factors affecting the gross margin of cassava farmers in the region. The choice of the model and estimation method was based on the fact that all dependent variables were greater than zero. Implicitly, the specified model is expressed as thus:

$$GMA = \emptyset_0 + \emptyset_1 AGE + \emptyset_2 EDU + \emptyset_3 MAR + \emptyset_4 HHS + \emptyset_5 EXP + \emptyset_6 SOC + \emptyset_7 CUT + \emptyset_9 FAS + \emptyset_{10} TRA + \emptyset_{11} GEN + \emptyset_{12} CRE + \mu_i \dots\dots\dots\dots\dots.(4)$$

where:

GMA = Gross margin of cassava farmer (Naira) in one production cycle
AGE = Age of a farmer (years)
EDU = Education of a farmer (years)
MAR = Marital status (dummy: 1 for married and 0 otherwise)
HHS = Household size (number)
EXP = Farming experience (year)
SOC = Member in social organization (year)
CUT = Cost of planting materials (Naira)
FAS = Land size (hectares)
TRA = Transportation cost (naira)
Sex = Sex of a farmer (dummy: 1 for female and 0 otherwise)
CRE = Access to farm credit (amount in Naira)

## RESULTS AND DISCUSSIONS

**Socio-economic characteristics of cassava farmer**

The social and economic characteristics of cassava farmers were analyzed and the results are presented in Table 1. The analyses revealed that the majority of the cassava farmers (70.80%) were females. The farmers' age showed an aging population with the majority (35.80%) greater than 50 years and a mean age of 44.3 years. The majority (67.40%) of the farmers were married. The mean farming experience of 11.9 years was obtained in the sample population. This implies that the majority of the cassava farmers are well experienced and this is a fundamental precursor for innovation adoption. It is also observed that the majority (98.40%) of the farmers are literate with an average year of learning of 13.1 years. Thus, the literacy level of cassava farmers is an enhanced opportunity for them to increase farm productivity. Furthermore, the social capital formation is averaged at six years. This implies that cassava farmers are socially oriented. In addition, an average household size of five members was discovered which means that family labour is important in cassava production. The analysis of the secondary occupation revealed that all cassava farmers have complementary livelihood sources. This means that the occupational diversification tendency is very high among small-scale farmers in the southern region of Nigeria.

Table 1. The Socio-economic characteristics of cassava farmers

| Characteristic | Freq. | % | Characteristic | Freq. | % |
|---|---|---|---|---|---|
| ***Farm income per year (Naira)*** | | | ***Distribution of Secondary occupation*** | | |
| <10,000 | 0 | 0.00 | Civil Servant | 16 | 13.50 |
| 10,001-20,000 | 37 | 30.80 | Pensioner | 38 | 31.60 |
| 20,001-40,000 | 10 | 8.30 | Artisan | 2 | 1.60 |
| 40,001-60,000 | 10 | 8.30 | Okada /Bus driver /Keke driver | 6 | 5.00 |
| 60,001-100,000 | 37 | 30.80 | Trading on Large Scale | 5 | 4.20 |
| >100,000 | 26 | 21.80 | Fishing | 12 | 10.00 |
| Total | 120 | 100.00 | Petty Trading | 41 | 34.10 |
| Mean | 68,694.17 | | Total | 120 | 100.00 |
| ***Marital Status of Farmer (number)*** | | | ***Age Distribution (Years)*** | | |
| Single | 35 | 29.20 | <20 | 1 | 0.80 |
| Married | 81 | 67.50 | 20 –30 | 23 | 19.20 |
| Divorced | 1 | 0.80 | 31– 40 | 32 | 26.60 |
| Widow | 3 | 2.50 | 41– 50 | 21 | 17.60 |
| Total | 120 | 100.00 | >50 | 43 | 35.80 |
| ***Farming Experience (Years)*** | | | Total | 120 | 100.00 |
| <1 | 0 | 0.00 | Mean | 44.3 | |
| 1-5 | 51 | 42.40 | ***Educational Qualifications (years)*** | | |
| 6-10 | 26 | 21.70 | No schooling | 2 | 1.60 |
| 11-15 | 8 | 6.70 | Primary | 4 | 3.40 |
| 16-20 | 9 | 7.60 | Secondary | 93 | 77.50 |
| >20 | 26 | 21.60 | Tertiary | 21 | 7.50 |
| Total | 120 | 100.00 | Total | 120 | 100.00 |
| Mean | 11.9 | | Mean | 13.1 | |
| ***Membership of Social Organization (years)*** | | | ***Mode of farmland acquisition*** | | |
| <1 | 71 | 59.20 | Inheritance | 82 | 68.30 |
| 1-5 | 10 | 8.30 | Leased | 22 | 18.30 |
| 6-10 | 7 | 5.80 | Contract | 1 | 0.80 |
| 11-15 | 6 | 5.20 | Purchase farm | 10 | 8.50 |
| 16-20 | 20 | 16.60 | Cooperative farm | 3 | 2.50 |
| >20 | 6 | 4.90 | Community farmland | 2 | 1.60 |
| Total | 120 | 100.00 | | | |
| Mean | 6.0 | | Total | 120 | 100.00 |
| ***Gender (number)*** | | | ***Farm Size (hectare)*** | | |
| Male | 35 | 70.80 | Less than 0.200 | 14 | 11.67 |
| Female | 85 | 29.20 | 0.201 – 0.400 | 27 | 22.50 |
| Total | 120 | 100.00 | 0.401 – 0.600 | 42 | 35.00 |
| | | | 0.601 – 0.800 | 30 | 25.00 |
| ***Family Size of Respondents (number)*** | | | 0.801 – 1.000 | 5 | 4.17 |
| 1-5 | 72 | 60.00 | Greater than 1.00 | 2 | 1.67 |
| 6-10 | 48 | 40.00 | Total | 120 | 100.00 |
| >10 | 0 | 0.00 | Maximum | 1.50 ha | |
| Total | 120 | 100.00 | Minimum | 0.10 ha | |
| Mean | 5.0 | | Mean | 0.59 ha | |

Source: compute by author, data from field work 2021.

About 98.33% of the cassava farmers' farmlands were less than one hectare, while the popular mode of land acquisition was through inheritance or family land. However, the average annual farm income of ₦68, 694.17 implies that most of the small-scale farmers in the region are resource-poor. Oladoyin et al., [35] and Akpan et al., [8] have reported similar results previously.

**The determination of the gross margin of Cassava farmers**

The results in Table 2 shows the frequency and percentage distribution of the gross margin of cassava farmers. The results revealed that majority (35.80%) of the farmers earned gross margin less than ₦10, 000. This clearly justified the small scale nature of cassava farmers in the study area. Only 0.80%

of the farmers generated farm income in excess of ₦100, 000.00. From the distribution of the gross margins, it is obvious that each farmer contribute insignificant share to the market supply of cassava. It is also likely that most cassava farmers devoted good proportion of their produces for home consumption while the minor portion is given out for sales.

Table 2. Gross margin distribution of cassava farmers

| s/n | Annual Gross margin range (₦) | Freq. | % |
|---|---|---|---|
| 1 | Less than 10,000 | 43 | 35.80 |
| 2 | 10,001 – 20, 000 | 20 | 16.70 |
| 3 | 20,001 – 40, 000 | 19 | 15.90 |
| 4 | 40,001 – 60, 000 | 25 | 20.80 |
| 5 | 60,001 – 80, 000 | 10 | 8.30 |
| 6 | 80,001 – 100, 000 | 2 | 1.70 |
| 7 | Greater than 100, 000 | 1 | 0.80 |
| 8 | Total | 120 | 100.00 |
| 9 | Mean | 29,793.57 | |

Source: compute by author, data from field work 2021.

Moreover, a mean gross margin of ₦29, 793.57 was estimated for the cassava farmers. However, the result further revealed that all cassava farmer earned positive gross margins. The findings imply that cassava production has potentials to generate stream of incomes and profits if farm resource are harnessed in an efficient manner. Another implication of the result is that, with efficient management technique, farm productivity can be enhanced within the frame work of small scale production.

**Determinants of the gross margin of Cassava farmers**

The factors that influence the gross margin of cassava farmers are presented in Table 3. The diagnostic statistics of the estimated equation revealed the at R – squared value of 0.5192, which implies that about 51.92% of the variability in gross margins of cassava farmers is connected to the specified explanatory variables.

This means that important variables that affect the gross margin of cassava farmers were included in the specified OLS model. The F – calculated value of 10.60 is statistically significant at 1.00% probability level. This means that the estimated gross margin equation has a goodness of fit. The null hypotheses are not rejected for the Breusch-Pagan test of heteroscedasticity and normality of the residuals. These imply that there are no significant issues of heteroscedasticity and the use of Ordinary Least Squares estimation method is justified. The null hypothesis for the RESET test is not rejected, hence the estimated equation has structural rigidity. The magnitude of the variance inflation factor (VIF) shows that there is no significant presence of collinearity among explanatory variables.

The empirical results indicate that the coefficient of age is positive and significant at 1% probability level. This implies that farmers' age has a strong positive relationship with the gross margin. By implication, it means that a 1 % increase in the age of cassava farmers would increase the gross margin by ₦292.30. The plausible reason for the result could be that older farmers are more experience and hence will adopt techniques that will help them allocate and combine farm resources efficiently. The finding corroborates the report of Akpan et al., [16]; Abebe et al., [1] and Akpan et al., [8].

The result further revealed that the coefficient of education has a positive significant relationship with the gross margin of cassava farmers. The result showed that an increase in a year of formal education will cause about ₦946. 91 increase in the gross margin of cassava farmers. The increase in years of formal education enhances the ability of a farmer to search and use new technology in addition to better market opportunities. Also, access to credit facilities is also enhanced by the level of literacy of the applicant. The findings are in consonance with Akpan et al., (2012); Akpan et al., [16]; Mersha, et al., [30]; Ehinmowo et al., [25]; Akpan et al., [13]; Akpan et al., [19].

The result also revealed that the increase in farmers' household size impacted negatively on their gross margins. The result showed that a number increase in the household size will reduce the gross margins by ₦1,852.83.

Table 3. Factors that affect the gross Margins of Cassava Farmers

| Variable | Coefficient | Std. Error | t-ratio | p-value | VIF |
|---|---|---|---|---|---|
| Constant | 6,083.32 | 14,393.8 | 0.4226 | 0.6734 | – |
| Age of a farmer | 292.304 | 105.311 | 2.776*** | 0.0074 | 2.075 |
| Education | 946.908 | 419.863 | 2.255** | 0.0395 | 1.275 |
| Marital status | −603.001 | 4,846.09 | −0.1244 | 0.9012 | 1.447 |
| Household size | −1,852.83 | 910.708 | −2.034** | 0.0444 | 1.247 |
| Farming experience | 41.8836 | 22.546 | 1.858* | 0.0696 | 2.524 |
| Socialization | 23.8788 | 13.071 | 1.827* | 0.0725 | 2.386 |
| Cassava cuttings | 0.197564 | 0.104439 | 1.892* | 0.0612 | 2.191 |
| Farm size | 35,042.3 | 10,548.2 | 3.322*** | 0.0012 | 2.539 |
| Transportation cost | −2.7563 | 0.979621 | −2.814*** | 0.0058 | 2.074 |
| Gender | 1,503.45 | 4,585.02 | 0.3279 | 0.7436 | 1.220 |
| Access to credit | −27,617.9 | 9,606.35 | −2.875*** | 0.0049 | 1.035 |
| **Diagnostic Tests** | | | | | |
| R-squared | 0.5192 | Normality test | | 1.9869 (0.8745) | |
| F(11, 108) | 10.6036*** | RESET test | | 1.2934(0.2786) | |
| Breusch-Pagan test | 1.4532 (0.7491) | Adjusted R-squared | | 0.4703 | |

Source: from data analysis using Gretl econometric software**.** The asterisks `*`, `**` and `***`shows significance at 10%, 5% and 1% probability level respectively'.

This relationship could be explained by the fact that farmers with large household size will likely met the financial obligations of their large family members rather than farm investment. The decision will likely lower farm investment, leading to lower input productivity and lower yields as well as lower-income and gross margin. Oladeebo and Oluwaranti [34]; Akpan et al., [16]; Mersha, et al., [30]; Abebe et al., [1]; Ehinmowo et al., [25]; Oladeebo and Oluwaranti [34]; Akpan et al., [13]; and Akpan et al., [19] confirm this report previously.

The coefficient of social capital formation is positively related to the gross margin of farmers. The findings revealed that a year increase in social capital formation will lead to about ₦23.88 increase in the gross margin of farmers. This could be as a result of the fact that farmers who belong to social groups have more avenues to interact with others thereby facilitating marketing and innovation usage. The finding agrees with Akpan et al., [16] and Abebe et al., [1].

Furthermore, the result revealed that access to farm credit correlates negatively with the gross margin of cassava farmers. It showed that increased access to farm credit will lead to about ₦27,617.9 decrease in the gross margin of farmers. This perhaps could mean that as farmers' access to farm credits increase; farmers will likely benefit from economies of scale that could lead to increase in the production cost and lesser gross margin. The issues of interest rate charge could also explain the result discussed above. Servicing a high-interest rate would reduce farm total income. Similar submission has been given by Akpan et al., [16].

The finding further reveals that farm size has a significant positive relationship with the gross margin of cassava farmers. It implies that as farmland increases, it leads to an increase in the gross margin by ₦35,042.3, at 1 % level of probability. This can be explained by the fact that an increase in farm size would lead to an increase in output and corresponding gross margins. The finding align with the submission of Mersha, et al., [30]; Oladeebo and Oluwaranti [34]; Akpan et al., [13] and Akpan et al., [19].

The result also reveals that cassava cuttings have a positive relationship with the amount of gross margin earned. The results showed a unit increase in the cassava cuttings will result to the increase of the gross margin marginally by ₦0.19 at 10% probability level. This result implies that as the cassava cuttings increase the gross margin of the farmer also increases. This can be as a result of increase in the plant population. Ridwan *et al.* [39]; Akpan et al.,

[16]; Mersha, et al., [30]; and Ehinmowo et al., [25] have reported similar result.

The result further reveals that an increase in transportation costs has a negative significant effect on the gross margin of the cassava farmers. That is, an increase in the cost of transportation will lead to a decrease in the gross margin. It implies that a unit increase in transportation cost, will leads to a decrease in the gross margin by ₦2.76, at a 1 % level of probability.

The coefficient of farming experience has a positive significant relationship with the cassava farmers' gross margin. A unit increase in the farming experience would trigger about a ₦41.88 naira increase in the farmers' gross margin. An increase in farming experience has a strong correlation with innovation adoption and the educational level of small-scale farmers. A farmer with an increase in farming experience has a very high tendency to avert risks in farming. Aversion of risks and uncertainties reduces production costs, while boosting total farm revenue. The finding is supported by Abebe et al., [1]; Ehinmowo et al., [25]; Akpan et al., [19] and Akpan et al., [8].

## CONCLUSIONS

Cassava production in the southern region (rainforest belt region) Nigeria is an integral part of the native culture, hence a veritable tools to combat rural poverty and ensuring self-food sufficiency in the region.

Therefore its sustainability and the future investment are conditioned on developing a sound policy framework based on empirical investigations.

As part of the contributions to develop a sustainable cassava production enterprise in the region, the study analyzed one of the indicators or indexes of sustainability known as the "gross margin".

The findings have revealed that women dominate cassava production population in the region, and the average population of cassava framers are moderately educated with more than a decade of farming experience and are in their active ages.

The findings further identified inheritance as the most popular mode of farmland acquisition while average farmland was less than one hectare and job diversification capacity was prominent.

The nature of the gross margins generated revealed great potential for improvement. The empirical findings revealed farmers' age, education, household, farming experience social capital, transaction cost, access to credit, and farm size including cassava cuttings as importance factors influencing gross margins of cassava farmers in the southern region of Nigeria.

Based on the empirical results, the following recommendations are prerequisites to achieving sustainability in the earned gross margins in cassava production:

(a)Youth should be encouraged to cultivate cassava and participate in its value chain as a business enterprises and to augment the current aging cassava population in the region.

(b)The study showed that advancement in education is an incentive that enhances gross margin among cassava farmers, hence adult education should be encouraged especially among rural based farmers.

(c)Moderate households size should be encourage among cassava farmers through child spacing and family planning programmes for rural based farmers.

(d)Subsidies on cassava cutting is encouraged as this will help to reduce production costs.

(e)Social capital formation is one of the prerequisites for enhancing gross margins, hence this should be encouraged among cassava farmers in the region.

(f)Provision of credit with minimum interest rate to cassava farmers is highly recommended.

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# STUDY ON THE PERCEPTION OF STUDENTS OF THE FACULTY OF MANAGEMENT AND RURAL DEVELOPMENT REGARDING THE TEACHING - LEARNING-ASSESSMENT ACTIVITY CARRIED OUT ONLINE DURING THE COVID-19 PERIOD

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***Abstract***

*The role of a higher education institution is to train specialists who have the necessary skills for their integration into the labor market. The Faculty of Management and Rural Development is one of the 7 faculties of the University of Agronomic Sciences and Veterinary Medicine in Bucharest and which, through the mission and objective, it has proposed as the university curriculum to increase the quality of the didactic act with the aim of training specialists who can integrate into the current knowledge-based society, specialists who can assume responsibilities, be creative, original, flexible, adaptable, with an analytical thinking, innovative and able to run businesses, so that the motto of the faculty is "Preparing to lead!". The new challenges facing today's society make higher education institutions rethink their priorities, having to continuously adapt to meet the challenges that accompany modern society. Therefore, they need modern teaching-learning-evaluation strategies, which respond to the changing requirements and require a digital transformation. The experience gained during the Covid-19 pandemic has accelerated progress in this direction, but more is needed so that the needs of young people raised in a digital society, with digital needs and digital skills can be met. The present study aims to measure the perception of the Faculty of Management and Rural Development students regarding the extent to which digital technology has been applied in the online teaching-learning-evaluation process and its effectiveness. The research methodology assumed the analysis of specialized literature regarding the use of digitization in the application of modern methods in the teaching-learning-evaluation process. The case study was carried out starting with a questionnaire that contained 15 questions addressed to the students of the Faculty of Management and Rural Development. The processing of the answers was carried out with the help of statistical methods, and the results obtained after their interpretation showed that both the teaching staff and the students adapted quite quickly to the online education system. The teaching-learning methods were varied, as were the learning tools used. Among the strong points of online education were flexibility, accessibility, and a variety of methods used in the teaching-learning activity, and among the weak points were identified: maintaining the students' attention during the teaching-learning activity, time management, or the level of digital skills of the teaching staff..*

***Key words*****:** *teaching-learning-evaluation methods, online education, digitization*

## INTRODUCTION

In a modern society, which registers an increasingly alert pace of development, digitization becomes one of the most important elements of the development of all the society's systems, and education, as its top sector, must constantly adapt to these changes. Digital technologies have an important role in improving the didactic process within higher education institutions, which contributes on the one hand to its modernization and development, and on the other hand to the development of skills that make it possible to integrate graduates into the labor market. And this time globalization can be brought into the discussion, as a phenomenon that has contributed to the change of society's development perspective and which is closely related to the structural changes of the labor market that have led to the transformation of higher education, to the need for its modernization and transition to digitization. The consequences of globalization are related to technological progress, to how it determined the development of economies and demographic development, with direct effects on the labor market [9]. On the other hand, economic growth is influenced by innovation [8], by the use of modern research technology, which aims at innovation and which benefits from the most modern technologies, i.e. digitization.

The digitization of education has been debated for a long time, trying to find answers regarding its effectiveness. Therefore, new forms of education have appeared (e-Learning, blended learning, etc.), different or combined with the classic systems, and which have come to the aid of people who wish to continue their education, but who, due to valid reasons (age, existing a job, social, economic reasons, etc.) would not have been able to do this [3]. These new forms of education involved both new educational resources and pedagogical methods adapted to the new conditions.

According to Aboagye et al., there is a difference between teaching, which can be done inside or outside the classroom, and e-learning or blended learning, as formal learning systems that are done with the help of computer technology and the Internet [1].

These systems were applied during the Covid-19 pandemic out of the need to quickly respond to the need to resume the education process and out of the desire to face the challenges and shortcomings that accompanied that period.

One of the few positive aspects of the Covid-19 pandemic was the development and use of technologies that allowed traditional activities to migrate online. These have allowed both work and education to take place remotely. Educational institutions went through a rapid experiment and had to adapt to these conditions, which brought unprecedented progress not only in the field of technology but also in that of pedagogy, which in turn became digital [14].

In this way, technology, and digitization were the ones that prevented the collapse of the educational system, but also of other aspects of life [13].

Online education has not appeared yet, because, at least in higher education, it has been practiced for a long time in the form of open distance education, blended learning, etc. which have granted certain flexibility in terms of teaching-learning-evaluation to respond pedagogically to the needs of students, without these processes being restricted by time, space or distance [6, 11]. And the development of such systems can only be possible through the development of digitalization, which can represent a factor of progress, but equally can lead to a decrease in the efficiency of the educational process when it is not adapted to the needs of students and teaching staff. Along with these changes, there is also a change in the role of the teacher who becomes a learning facilitator, mentor, and research partner who offers students the opportunity to acquire the skills they need, innovating and developing new teaching methods taking into account the learning needs of students, by the learning context, but also by their individual interests [7].

The success of online education, therefore, depends not only on the existence of platforms, technology, and digitization but also on the implementation of the principles of modern pedagogy, on respecting confidentiality, the rights of individuals, etc.

No matter how efficient the technologies used in the educational process are, they cannot replace the pedagogical part, which must subordinate digitization [17].

The learning activity during the Covid-19 pandemic can be considered experiential learning because the students operated with experiences, and concepts, checking the implications that their use had in achieving the objectives. This process is complex, and it could not be optimal without the use of suitable pedagogical methods, because it would complicate the instructive-educational activity, which could lead to abandonment [2].

The success of online education, from a pedagogical point of view, is ensured on the one hand by personalization, authenticity, and collaboration [5, 12], and on the other hand by the use of technology to support pedagogy.

These elements improve both the learning experiences and the students' motivation to achieve the objectives [4, 15].

Digitization of education is a complex process, which, in addition to ICT tools, also requires new teaching methods that lead to the improvement of the quality of education. Therefore, digitization and the structure of the curriculum are interdependent elements, because any technological change is accompanied by new requirements regarding the contents and pedagogical methods used [16].

In Romania, the problem of digitization is not a new one, its foundations were laid in 2016 through the "Educated Romania" project, which involved a public debate and which carried out the projection of the future, imagining its challenges for the present society [10]. The 15 education transformations included in the public debate were proposed for the next period, until 2030.

Therefore, the digitization of education had begun before the onset of the Covid-19 crisis, which represented a way to face new challenges, accompanied by numerous difficulties.

To the same extent, however, the return to the classical education system, after the online period, affected the way education is carried out.

## MATERIALS AND METHODS

The research methodology assumed, on the one hand, the analysis of the specialized literature regarding the use of digitization in the development of higher education, and on the other hand, a quantitative study carried out by applying a questionnaire consisting of 15 questions to the target group.

The target group was represented by the students of the Faculty of Management and Rural Development, from years II, III, and IV. During the survey, a sample was not created, but a questionnaire was developed that was completed online by the students.

The questionnaire was applied between May and June 2022, and the number of respondents was 131.

The evaluative questions on which the study was based were the following:

Q1-Did you participate in online courses and seminars?

Q2-What was the level of attendance at the online courses and seminars?

Q3-Did you manage to adapt to the form of online teaching-learning?

Q4-What was the effectiveness of online teaching-learning?

Q5-Were interactive teaching methods used in the teaching process?

Q6-What was the degree of use of these methods?

Q7-What were the resources used in the online teaching-learning process?

Q8-Which of the following tools were used in online teaching-learning?

Q9-How were the workloads received for the online activities?

Q10-How satisfied were you with the effectiveness of online teaching?

Q11-What were the main obstacles in the transition to online education?

Q12-What were the main advantages of online education?

Q13-What will you miss the most during online interaction compared to face-to-face teaching?

Q14-Can the online teaching-learning activity replace the face-to-face activity?

Q15-What were the problems that arose with the online assessment?

*To answer these questions, the questionnaire covered the following aspects*:

• the quality of the instructional-educational activity;

• online teaching-learning results;

• the effects, at the individual level, of the online teaching-learning system;

*The assessment limits were given by*:

• the collected information that was, in general, at the level of perceptions;

• the survey was based on a questionnaire that was carried out only for students, data were not collected from teaching staff;

• the difficulties of attributing the effects declared by the respondents;

• lack of control groups.

• data analysis was done only through descriptive statistical methods.

*Characteristics of the group of respondents*

32 students from the second year, 51 students from the third year, and 48 students from the fourth year answered the questionnaire. Data processing was done using statistical methods, the results being then presented through the interpretations, tables, and graphs in the paper.

## RESULTS AND DISCUSSIONS

The present study was carried out based on data collected with the help of a questionnaire, which included 15 questions related to the learning experience of the students of the Faculty of Management and Rural Development during the Covid-19 pandemic. The demographic data regarding the respondents are presented in table 1, noting that 63% of the respondents were women, and 37% were men. The distribution by years of studies shows that 39% of the respondents are students in the third year of study, 37% in the fourth year, and 24% in the first year of study.

Table 1. Demographic information

| | Type | Frequency | % |
|---|---|---|---|
| Sex | Female | 82 | 62.60 |
| | Male | 49 | 37.40 |
| Year of Study | II | 32 | 24.42 |
| | III | 51 | 38.93 |
| | IV | 48 | 36.65 |

Source: own processing.

To the first question: *Have you participated in online courses and seminars*? we note that all respondents participated in online activities during the Covid-19 period, this being the mandatory condition for the promotion of the academic year. At the same time, another reason for participating in the online activities was the novelty of the system and the possibility of interaction with colleagues and teaching staff at a time when everyone was isolated.

To question no. 2: *What was the degree of attendance at the online courses and seminars?* we find that 59% of the students of the Faculty of Management and Rural Development had a presence between 76-100% regarding the courses and seminars held online, while 17% of them had a presence between 25-50%, the reasons being related to the existence of a job, the occurrence of technical problems or the lack of electronic devices that would allow them to log in under good conditions for attending classes or seminars (Figure 1).

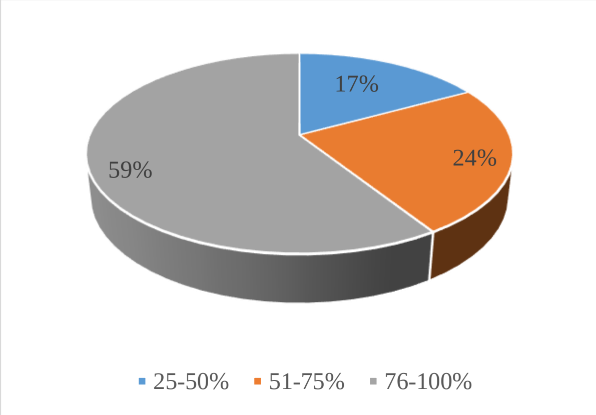


Fig. 1. Share of participation in online activities
Source: own processing.

To question no. 3: *How did you adapt to the form of online teaching-learning?*, we find that of the total number of respondents, 21% adapted very easily, 61% adapted easily, and 18% adapted moderately to this form of teaching-learning. Although in the questionnaire there were also difficult and very difficult options, they were not chosen as answers. Thus, we find that the students had no difficulties in adapting to the new system, in this sense their digital skills were useful to them (Figure 2).

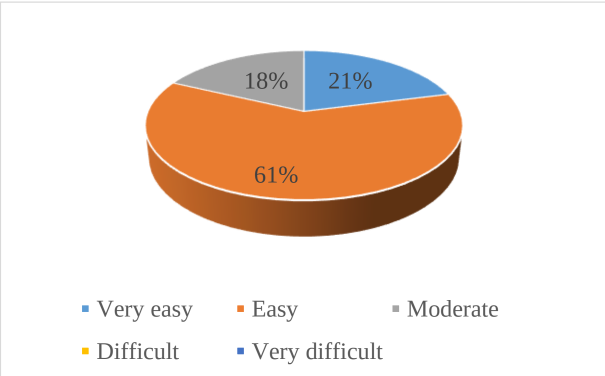


Fig. 2. The situation of students' adaptation to the online teaching-learning system
Source: own processing.

Question no. 4 referred to the efficiency of the teaching-learning activity carried out in the online system.

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From the answers collected based on the questionnaire, we find that 9% of the students consider that the efficiency of the teaching activity was less than 25%. Most of them (48%) believe that the efficiency was between 51-75%, while 22% of the students believe that it was over 75% (Figure 3).

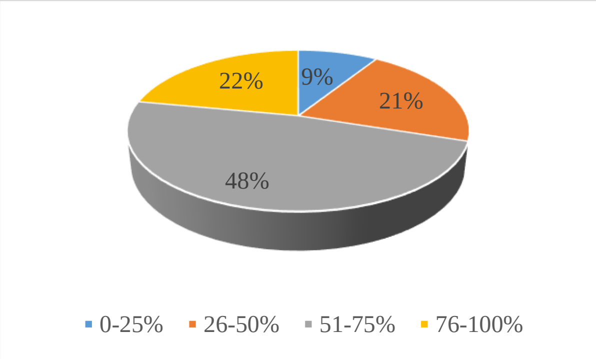


Fig. 3. The situation of the effectiveness of online teaching-learning
Source: own processing.

To question no. 5: *Were interactive teaching methods used in the teaching process?* 87% of the respondents believe that such methods were used, while 13% believe that they were not used.

To question no. 6. *Regarding the degree of use of the methods in the online teaching activity*, 17% of the respondents considered that the use of these methods was below 25%, while 20% considered that the interactive methods were used in a higher proportion of 75%.

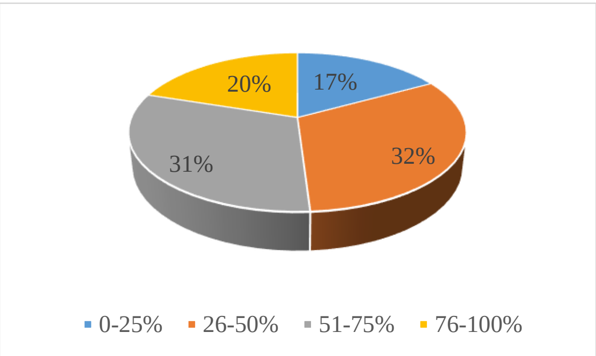


Fig. 4. Share of the use of interactive teaching methods
Source: own processing.

At the same time, 32% of students, respectively 31% considered that interactive methods were used in proportions between 26-50%, respectively 51-75%, which demonstrates the fact that, in general, students considered the teaching activity as being an interactive one (Figure 4).

To question no. 7: *What were the resources used in the online teaching-learning process?* the answers received showed that different educational resources were used during the teaching-learning activity.

We find that all the responding students used the university's platform. 92% of them communicated with the teaching staff by email, as a result of the fact that the course and seminar materials were sent to them in this way. A share of 76% of students used the Google Classroom platform, and 78% of them used the Google Meet platform. The least used resource was the Microsoft Teams platform, with only 22% of students using it (Figure 5).

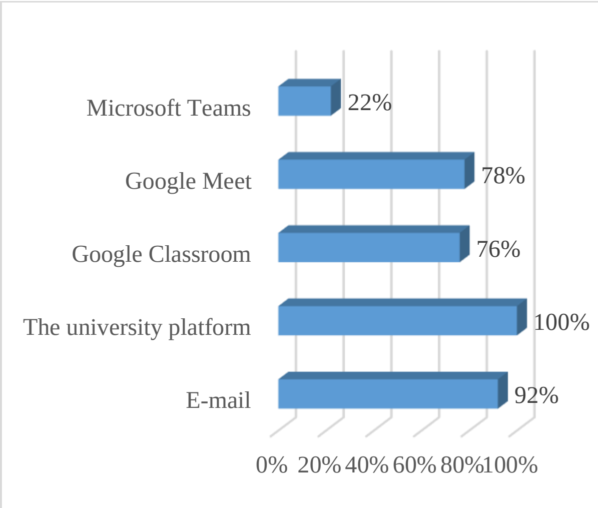


Fig. 5. Share of the use of educational resources
Source: own processing

To question no. 8. *Regarding the means used in online teaching-learning*, the students appreciated that in 92% of cases different digital materials were used (PPT, Prezi, etc.), and 42% appreciate that they were involved in didactic games (Tenty questions, Pictionary, Taboo, etc), 37% used different learning platforms (Kahoot, Socrative, Gimkit, etc), and 2% used other teaching-learning means.

To question no. 9: *How do you rate the tasks received for the online activities?*, the answers show that 58% of the responding students considered the tasks as attractive, and 35% of them as unattractive. 7% of them were undecided about answering (Figure 6).

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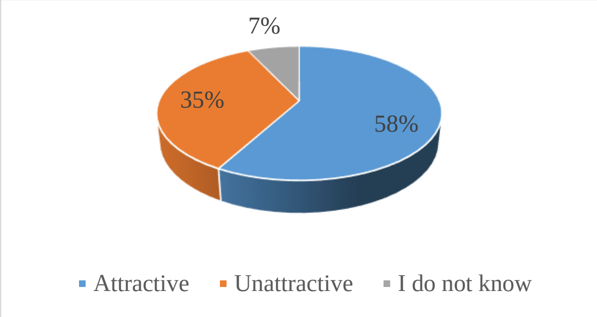


Fig. 6. Assessment of the degree of attractiveness of work tasks
Source: own processing.

To question no. 10: *How satisfied were you with the effectiveness of online teaching?*, 2% of respondents were dissatisfied, and 7% were not satisfied, considering that online teaching was not effective for them. On the other hand, 43% of the respondents were very satisfied, 26% satisfied, and 22% moderately satisfied, which indicates that in general, both students and teachers managed to switch to the online teaching system in a short time and adapt to this new experience (Figure 7).

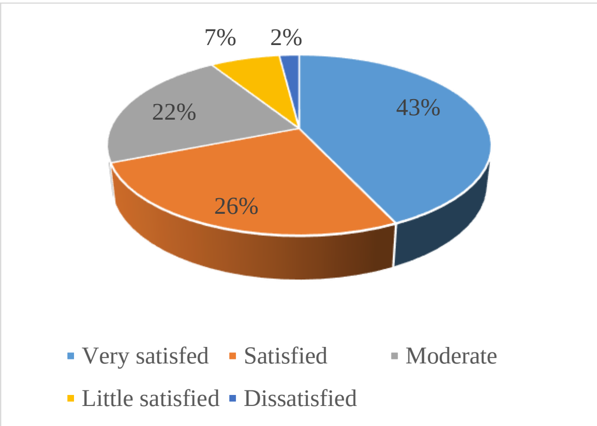


Fig. 7. Degree of satisfaction with the online teaching-learning activity
Source: own processing

Questions 11 and 12 tried to identify *the strengths and weaknesses related to online teaching*, as they were perceived by the students of the Faculty of Management and Rural Development.

Regarding the weak points of the online teaching process, the answers were, in the order of the answers offered, the following: the efficiency of maintaining the students' attention/motivation/involvement in the teaching activity; time management; the teacher's access to technology; the low level of digital skills of the teacher; student access to technology; other causes; the low level of digital skills of the student (Figure 8).

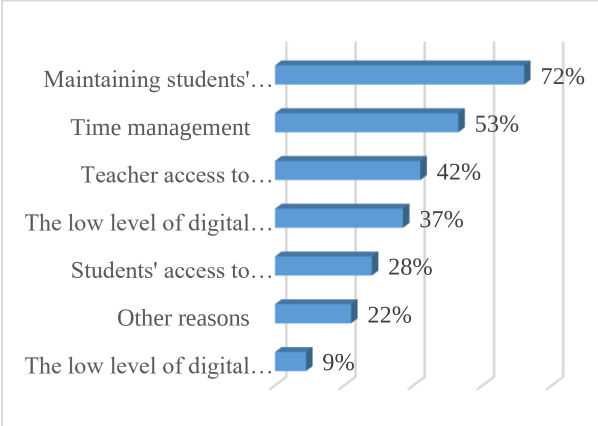


Fig. 8. The weak points of online teaching
Source: own processing.

The strong points of online teaching were represented, in the order of the assessments made by the students, the following: flexibility; accessibility; ease of use of technology; the variety of work tools; innovation; autonomy and motivation; other reasons (Figure 9).

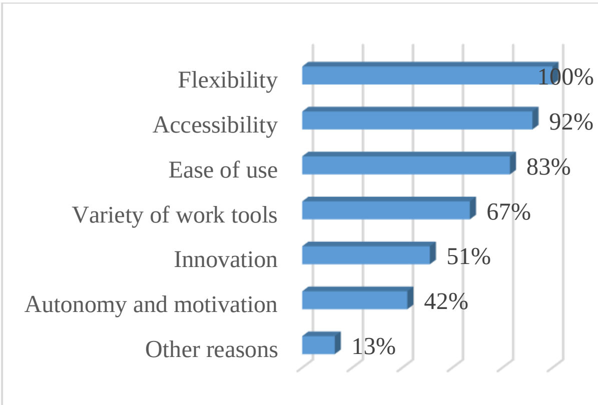


Fig. 9. Strengths of online teaching
Source: own processing.

To question no. 13: *What did you miss the most during online interaction compared to face-to-face teaching?*, most of the respondents (57%) considered that interaction with colleagues was what they missed; 45% considered that interaction with teachers was what they lacked; 19% considered it a learning space and the fact that they had to share the same space with other colleagues (those from the student dormitories) or with

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other family members, was what disturbed their educational process.
17% of the students had various other reasons or causes, and 9% of them considered that they lacked all these aspects (Figure 10).

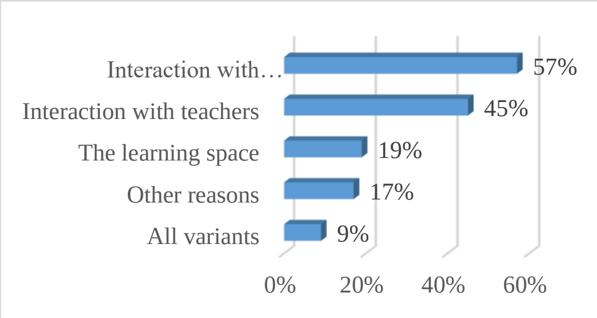


Fig. 10. The aspects that were missing during the online activities
Source: own processing.

To question no. 14. *When asked about the possibility of replacing the face-to-face teaching-learning activity with the online teaching-learning activity*, only 2% of the respondents believed that this could not be possible, while 47% of the respondents believed that this may be possible, and 51% considered that the 2 categories of activities can be complementary.
To question no. 15. The last question of the questionnaire tried to identify *the difficulties of the respondents regarding the assessment activity carried out online.*
Thus, it was found that most problems were technical, but in a proportion of 9%, there were also problems related to understanding the subjects.
At the same time, 23% of the respondents did not have any problem with the online evaluation (Figure 11).

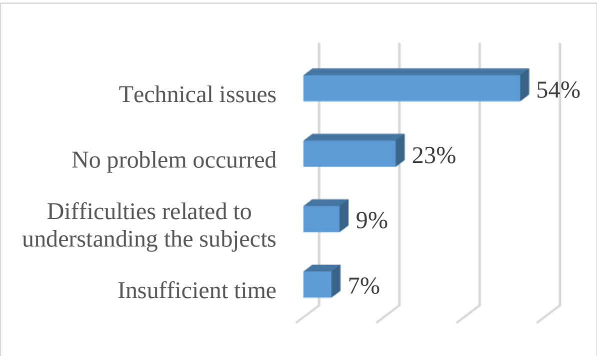


Fig. 11. The aspects that were missing during the online activities
Source: own processing

## CONCLUSIONS

The Covid-19 pandemic has demonstrated the fact that digitization is becoming more and more important, contributing to the modernization of education, to the development of new skills that will help future graduates to adapt to the conditions imposed by the labor market.
The current study showed that one of the problems related to online education was that of training, involving students in participating in the teaching activity.
The teaching-learning methods used were varied, as were the means of learning. Among the strong points of online education were flexibility, accessibility, and the variety of methods used in the teaching-learning activity, and among the weak points were identified: maintaining the students' attention during the teaching-learning activity, time management, or the low level of skills in digital tools of the teaching staff. The causes that prevented the evaluation activity were related to technical difficulties, insufficient time, or misunderstanding of work tasks.
The transition to online education during the pandemic demonstrated the ability of higher education institutions to adapt to the new conditions, to ensure the continuity of activities, even if they encountered difficulties and even if they still have many aspects to improve.
Digitization of education is no longer an option, but a necessity, thus ensuring the transition from traditional to modern education. However, it requires the existence of a well-trained human resource in the digital field, which can face the demands of the young people it trains.

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# STUDY ON USEFUL AND HARMFUL BEETLE SPECIES IN THE GUȘTERIȚA AGROECOSYSTEM, SIBIU COUNTY, ROMANIA

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***Abstract***

*Research in the "Priestess's Garden" of Gustrita began in 2014. The agro-ecosystem combines traditional gardening with the current ecological precepts of biodiversity. As method, there were used Barber traps with the help of which 383 Coleoptera beetles were caught. After sorting the entomological material in the systematic laboratory, a number of 61 species, 38 genera, 14 families of Coleoptera were identified. The ratio of useful species (51 species) to harmful species (10 species) is clearly in favor of the first category, which proved to be highly effective in depressing and controlling phytophages.*

***Key words***: *entomofauna, coleoptera, ecological garden, Gusterița, Sibiu county*

## INTRODUCTION

Famous is the "Gușteriței Hill" with its belvedere tower, from the height of which, in the harsh but clear mornings of spring, you can look out over the Hârtibaciului Valley, Secașelor Plateau, the Depression of Sibiu, to the distant heights of the Făgăraș Mountains.
The hill in the center of Gusterita (today a district of Sibiu) is a real acropolis on which the medieval buildings of the community were built: the church, the parish house and the parish school.
The church is one of the 600 fortified churches in Transylvania and one of the 150 churches that still exist. It was built at the beginning of the XIII-century as a Roman basilica and received its final Gothic aspect in the XVI century, as a fortress - church.
Towards the south-eastern side of the hillock, the slope descends slowly till the wall of the precincts that bounds a large area, which formerly was used as a refuge for villagers and their goods, during distressing times.
In the long run, this space was turned into a vegetable garden, and it was nicknamed "the Priestess Garden".
Here an extensive agricultural-educational exercise has been developed that combines traditional gardening with current ecological precepts of biodiversity.
The scientific studies undertaken so far [1], [2] have elevated it to a successful "biological experiment" with a definite tinge of originality.
The studies concerning in-vertebrata fauna that divide the species of the agro-ecosystem in two parts (useful and pest) are interesting and prove the important role of the entomofauna. This is man's great and unseen allied army that ensures the circuitry of organic matter in nature. The subtle interplay of the entomofauna of the agroecosystem must be understood and interventions must be judicious and ensure the optimal balance between useful and harmful entomofauna so that the circuits that prepare plant food function, ensuring sustainable fertility. As an entomological regulating factor for wildlife, the "entomological guesthouse" was established. This cultivates fauna with a role in regulating the balance between the two components, inhibiting, or keeping harmful fauna below the damage threshold.

## MATERIALS AND METHODS

The experiment took place between May and October 2015, in the "Priestess' Garden" in the Gușterița district, Sibiu.

In the experimental plot, the cultivation technology applied was in line with the concept of organic farming. Thus, the following are used: appropriate tools with a role in protecting the soil and its fauna, green manure, compost, soil mulching technique, natural bioactive preparations, untreated seeds, crop rotation, allelopathy, cultivation of plants in concentric strips, stagnant water for watering, cultural hygiene [1], [2].

The analyzed biological material includes 383 coleopteran specimens (adults, larvae), collected using Barber traps. This is the classical method for the continuous collection of beetles from the ground, both day and night. A trap consists of a 400-450 ml container. The traps were buried in the ground so that there was no difference in level between the top lid of the trap and the ground level, and a gap of 3 cm between the trap and the trap lid. The formaldehyde was used as an attractant.

The biological material, captured in every trap, was moved into another plastic container in 70 % alcohol, that constituted a sample collected during a period of 48 hours. There were 10 pcs. Barber's traps with a 10 m distance between them. During this experiment, 80 samples were collected. They were selected by families, genera and species, in the systematic laboratory.

The laboratory phase includes sample unpacking, labelling, numbering, determination. For this last operation, a large number of determinators were used [5], [9], [12], [13], [17].

## RESULTS AND DISCUSSIONS

We studied the Order Coleoptera because it includes species from different trophic categories (zoophagous, coprophagous, detritivores, necrophagous, phytophagous), components of most food chains in terrestrial ecosystems [20]. Many species of *Coleoptera* are important bio-indicators that bring useful information about the health of the ecosystem; they offer data concerning about the quality and the durability of life.

Ecological agriculture has an important objective, that is the knowledge and the protection of the useful species that are responsible with the maintaining the pest populations under the damage limit.

In this research work, there were identified 61 species of *Coleoptera* that belong to a number of 14 families (*Carabidae*, *Silphidae*, *Nitidulidae*, *Staphylinidae*, *Cantharidae*, *Elateridae*, *Histeridae*, *Chrysomelidae*, *Curculionidae*, *Anthicidae*, *Monotomidae*, *Scarabaeidae*, *Lathridiidae*, *Coccinelidae*) and 38 genera (*Poecilus*, *Amara*, *Pterostichus*, *Harpalus*, *Bembidion*, *Acupalpus*, *Silpha*, *Nitidula*, *Carpophilus*, *Staphylinus*, *Actobius*, *Atheta*, *Bolitobius*, *Calodera*, *Ocalea*, *Omalium*, *Oxytelus*, *Oxypoda*, *Quedius*, *Aleochara*, *Heterothops*, *Philonthus*, *Tachyporus*, *Tachinus*, *Microglossa*, *Lathrobium*, *Scopaeus*, *Cantharis*, *Drasterius*, *Hister*, *Longitarsus*, *Chaetocnema*, *Sitona*, *Anthicus*, *Monotoma*, *Aphodius*, *Corticarina*, *Tytthaspis* (Table 1).

Table 1. The faunistical spectrum of the coleoptera in the ecological garden in Gusterita (Sibiu county)

| Taxa | Numerical abundance | Relative abundance (%) |
|---|---|---|
| **Carabidae** | | |
| **Poecilus cupreus* L. | 26 | 6.78 |
| +*Amara ovata* Dej. | 1 | 0.26 |
| +*Amara aenea* Dej. | 6 | 1.56 |
| +*Amara concinna Zimm.* | 9 | 2.34 |
| **Pterostichus niger* Schall. | 1 | 0.26 |
| +*Harpalus distinguendus* Duft. L. | 14 | 3.65 |
| +*Harpalus griseus* Panz. | 2 | 0.52 |
| +*Harpalus pubescens* Müll. L. | 1 | 0.26 |
| **Bembidion splendidum* Strm. | 20 | 5.22 |
| **Bembidion properans* Steph. | 3 | 0.78 |
| **Bembidion* sp. (lv.) | 2 | 0.52 |
| **Acupalpus meridianus* L. | 1 | 0.26 |
| **Silphidae** | | |
| **Silpha carinata* Herbst. | 9 | 2.34 |
| **Silpha carinata* Herbst. (lv.) | 3 | 0.78 |
| **Nitidulidae** | | |
| **Nitidula carnaria* Schall. | 22 | 5.74 |
| **Carpophilus bipustulatus* Er. | 95 | 24.80 |
| **Staphylinidae** | | |
| **Staphylinus similis* F. | 8 | 2.08 |
| **Actobius cinerascens* Grav. | 1 | 0.26 |
| **Atheta sordidula* Er. | 7 | 1.82 |
| **Atheta tabida* Kiesw. | 3 | 0.78 |
| **Bolitobius pygmaeus* Er. | 1 | 0.26 |
| **Calodera nigrita* Mnnh. | 1 | 0.26 |
| **Calodera uliginosa* Er. | 1 | 0.26 |
| **Ocalea picata* Steph. | 16 | 4.17 |
| **Ocalea badia* Er. | 6 | 1.56 |

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| | | |
|---|---|---|
| **Omalium oxyacanthae* Grav. | 1 | 0.26 |
| **Oxytelus insecatus* Grav. | 53 | 13.83 |
| **Oxytelus opacus* Er. | 2 | 0.52 |
| **Oxytelus sculptus* Grav. | 1 | 0.26 |
| **Oxytelus sculpturatus* Grav. | 1 | 0.26 |
| **Oxytelus piceus* L. | 1 | 0.26 |
| **Oxypoda elongatula* Aubé. | 2 | 0.52 |
| **Oxypoda vittata* Märkel | 7 | 1.82 |
| **Oxypoda spectabilis* Märkel | 1 | 0.26 |
| **Quedius ventralis* Arag. | 3 | 0.78 |
| **Aleochara laevigata* Gyll. | 1 | 0.26 |
| **Aleochara clavicornis* Redtb. | 13 | 3.39 |
| **Aleochara moerens* Gyll. | 8 | 2.08 |
| **Aleochara intricata* Mnnh. | 1 | 0.26 |
| **Aleochara lata* Grav. | 1 | 0.26 |
| **Aleochara crassicornis* Lac. | 1 | 0.26 |
| **Heterothops binotata* Grav. | 1 | 0.26 |
| **Philonthus aerosus* Kiesw. | 1 | 0.26 |
| **Tachyporus nitidulus* F. | 2 | 0.52 |
| **Tachinus collaris* Grav. | 1 | 0.26 |
| **Microglossa pulla* Gyll. | 1 | 0.26 |
| **Lathrobium sodale* Kr. | 1 | 0.26 |
| **Lathrobium quadratum* Payk. | 2 | 0.52 |
| **Lathrobium spadiceum* Er. | 2 | 0.52 |
| *Scopaeus cognatus* Rey. | 2 | 0.52 |
| **Cantharidae** | | |
| **Cantharis violacea* Payk.♀ | 1 | 0.26 |
| **Cantharis fusca* L. | 4 | 1.04 |
| **Cantharis* sp. (lv.) | 6 | 1.56 |
| **Elateridae** | | |
| +*Drasterius bimaculatus* Rossi | 9 | 2.34 |
| **Histeridae** | | |
| **Hister sepulchralis* Er. | 1 | 0.26 |
| **Chrysomelidae** | | |
| +*Longitarsus anchusae* Payk. | 1 | 0.26 |
| +*Chaetocnema tibialis* Illig. | 2 | 0.52 |
| **Curculionidae** | | |
| +*Sitona crinitus* Herbst. | 2 | 0.52 |
| **Anthicidae** | | |
| **Anthicus floralis* L. | 1 | 0.26 |
| **Monotomidae** | | |
| **Monotoma spinicollis* Aubé | 2 | 0.52 |
| **Scarabaeidae** | | |
| **Aphodius granarius* L. | 3 | 0.78 |
| **Aphodius varians* Duft. | 1 | |
| **Lathridiidae** | | |
| +*Corticarina gibbosa* Herbst. | 1 | 0.26 |
| **Coccinellidae** | | |
| **Tytthaspis* (*Micraspis*) *sedecimpunctata* L.a.12-*punctata* L. | 1 | 0.26 |
| **Total** | **383** | **100%** |
| * useful species<br>+ pest species | | |

Source: Own experiment and calculation.

The best represented family of *Coleoptera* is the *Staphylinidae* family (35 species) followed by *Carabidae* (12 species). In opposition to them, the *Nitidulidae*, *Cantharidae*, *Chrysomelidae*, *Scarabaeidae* families have only two species each. The *Silphidae*, *Elateridae*, *Histeridae*, *Curculionidae*, *Anthicidae*, *Monotomidae*, *Lathridiidae*, *Coccinelidae* families have only one species each.

In Table 2, the taxonomical and also the identified quantitative structure of the *Coleoptera* resulting from the research field in the Gusterița agro-ecosystem are presented.

Table 2. The taxonomical and quantitative structure of the fauna of *Coleoptera*, collected by means of the Barber's traps in the Gusterita agro-ecosystem

| Taxa | Numerical abundance | Relative abundance |
|---|---|---|
| Carabidae | 86 | 22.45 |
| Silphidae | 12 | 3.13 |
| Nitidulidae | 117 | 30.52 |
| Staphylinidae | 133 | 34.72 |
| Cantharidae | 11 | 2.87 |
| Elateridae | 9 | 2.34 |
| Histeridae | 1 | 0.27 |
| Chrysomelidae | 3 | 0.78 |
| Curculionidae | 2 | 0.54 |
| Anthicidae | 1 | 0.26 |
| Monotomidae | 2 | 0.54 |
| Scarabaeidae | 4 | 1.04 |
| Lathridiidae | 1 | 0.27 |
| Coccinellidae | 1 | 0.27 |
| Total | 383 | 100.00 |

Source: Own calculation.

The family with the highest quantitative abundance is represented by *Staphylinidae* - 133 samples (34.72%), followed by *Nitidulidae* family - 117 samples (30.52%) and *Carabidae* - 86 samples (22.45%). Among the families with a small numerical abundance are: *Silphidae* - 12 samples (3.13%), *Cantharidae* - 11 samples (2.87%), *Elateridae* - 9 samples (2.34%), *Scarabaeidae* - 4 samples (1.04%), *Chrysomelidae* - 3 samples (0.78%), *Curculionidae* - 2 samples (0.54%) and *Monotomidae* - 2 samples (0.54%), *Histeridae*, *Anthicidae*, *Lathridiidae*, *Coccinelidae*, each of them - 1 sample (0.27%).

In the mobile fauna on the surface of the soil, the *Staphylinidae*, *Nitidulidae*, and *Carabidae* families were dominant.

The pest coleoptera in the agro-ecosystem Gusterița are represented by 10 phytophagous species that belong to 5 families. They totalized a small number of individuals: 39 (10.18%). The useful coleoptera are represented by 51 species that belong to 10 families. They totalized 344 individuals that represent 89.82% from the total samples collected by making use of the Barber's traps. In the useful component they were identified zoophagous, detritophagous and coprophagous species.

**(1) In the first category of the phytophagous** species we remarked the following:

*Amara ovata* Dej., *A. aenea* Dej., *A.concinna* Zimm., species of *Carabidae*, produce a lot of damages to the cultivated plants, attacking them when they are young. *Amara ovata* Dej. attacks with predilection the species of the *Brassicaceae* family [15], [17].

*Harpalus distinguendus* Duft.L., *H. griseus* Panz., *H. pubescens* Mull. L. attack the germinated seeds, strawberries and young plants and *Bembidion properans* Steph., attacks the young plants [8].

*Drasterius bimaculatus* Rossi (*Elateridae*) attacks the plants on the surfaces with herbs [6].

All the species of the *Chrysomelidae* family are phytophagous. *Longitarsus anchusae* Payk. produce damages on herbs and it could be also due to the pest for the species of the *Plantaginaceae*, *Asteraceae*, *Scrophulariaceae*, *Boraginaceae* and *Convolvulaceae* [19]; The *Chaetocnema tibialis* Illig. species attack the beet and the spinach.

The *Sitona crinitus* Herbst. (*Curculionidae*) attack species of the Fabaceae. The adult feeds on the foliar apparatus of the seedlings, the plant suffers because the photosynthesis process is drastically reduced, the larvae feed on the root systems and their nodes, thus decreasing the plant's ability to fix atmospheric nitrogen [10], [14].

**(2) From the category of useful species** we highlight the presence of zoophagous species. They are extremely important in the agroecosystem, being biotic factors in the natural control of pest populations and 'key' links in the trophic structure of the biocenosis. They are found in several families of *Coleoptera*:

From family *Carabidae*: *Poecilus cupreus* L. which attacks the eggs of the Colorado beetle, larva of *Tentredinidae* and *Aphidae* [21]; *Pterostichus niger* Schall., which feeds with eggs and larvas of the mole cricket; *Bembidion splendidum* Strm., which feeds with larva of *Curculionidae* and *Heteroptera*. About *Bembidion properans* Steph., the researches certified that it has a role in the reduction of the larva of *Elateridae* [3], *Acupalpus meridianus* L., is considered by some scientific investigators, to be omnivorous. It is known the fact that, from the trophic point of view, there is not a definite limit between the predatory and the omnivorous insects.

The *Staphylinidae* family includes useful species, most of them being predatory species, among them we could find: the larva of *Staphylinus similis* F. that burrow galleries in soil and chase caterpillars, worms and small insects; the two species *Ocalea picata* Steph. and *Ocalea badia* Er. [4]; *Bolitobius pygmaeus* Er.; *Oxytelus insecatus* Grav. that attacks the pupa of *Delia brassicae* Bouche or it is considered as detritophagous; Oxypoda *vittate* Märk., *Tachyporus nitidulus* F. that could attack the pupa of *Delia brassicae* Bouche; *Philonthus aerosus* Kiesw. and also *Atheta sordidula* Er. and *Atheta tabida* Kiesw. [18].

*Cantharis violacea* Payk and *Cantharis fusca* L., (*Cantharidae*) play an important role in the biological control of the aphid *Myzus cerasi* F. and of the other small insects.

The *Histeridae* family is represented by only one species: *Hister sepulchralis* Er. The larva of this coleoptera are predators, the adults are necrophagous or coprophagous.

The representants of the *Coccinellidae* family are in their majority zoophagous. *Tytthaspis (Micraspis) sedecimpunctata* L. a.*12-punctata* L., attacks aphids, acariennes and tripsh. Some specialists affirm that this species is mycetophagous [16].

The detritophagous coleoptera are also useful. They feed with fragments of organic material resulted from the crumb and the partial decomposition of the dead plants and animals.

In the majority, the *Silphidae* family includes species found on dead bodies, rotten fungus, and on the other vegetal and animal matters in decomposition [11]. In the studied ecosystem it was identified the *Silpha carinata* Herbst. species

The *Nitidulidae* family registered the highest number of the collected insects. They feed on decaying vegetal matter. Such a trophic system have also the *Nitidula carnaria* Schall. and *Carpophilus bipustulatus* Er. species.

In the *Staphylinidae* family there are species that belong to the *Atheta, Omalium, Oxytelus, Tachyporus, Lathrobium* and *Aleochara* genera; they were found on the decaying vegetal matters, compost and on the tree moss [11].

In the *Anthicidae* family there are phytophagous species, but the *Anthicus* genus includes species that feed on decaying vegetal matters, as *Anthicus floralis* L. [7], [17].

The *Monotomidae* family is represented by *Monotoma spinicollis* Aube that appears often in decaying vegetal matter, inclusive in the artificial habitats like the heaps of compost.

The *Lathridiidae* family is represented in agro-ecosystem by *Corticarina gibbosa* Herbst. that is considered to be mycetophagous and not to produce damages [22].

They were identified also the coprophagous species that belong to the *Scarabaeidae* family: *Aphodius granarius* L., *A. varians* Duft that consume the catabolic produces of different animals mainly vertebrata, produces that are to be found in the manure of the stable.

Detritus- and coprophagous insects are considered "crop sanitarians" and provide bacteria and fungi with the resources needed for the mineralisation process. Their actions successfully place them in the category of useful insects.

## CONCLUSIONS

The list of beetles in the Gusterita Ecological Garden includes a total of 14 families, 38 genera and 61 species.

Surveys revealed the spectrum of beetles: 10 harmful species belonging to five families and 51 useful species belonging to 10 families.

The family with the highest numerical abundance is represented by *Staphylinidae* - 133 samples (34.72%), followed by *Nitidulidae* - 117 samples (30.52%), and *Carabidae* - 86 samples (22.45%).

The group of the useful species is characterized by dominance of the detritivorous species *Carpophilus bipustulatus* Er. (24.80%) and *Nitidula carnaria* Schall (5,74%) and the zoophagous species *Oxytelus insecatus* Grav. (8.61%) and *Poecilus cupreus* L. (6.78%).

The dominance of the useful coleoptera (89.82%) in comparison with the pest species (10.18%) emphasizes that at the level of the Guşteriţa agro-ecosystem, cultivated in the ecological manner, the useful species are efficient in inhibiting and keeping under control both the number of the pest coleoptera and also of other in-vertebrata in the agro-ecosystem.

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# PRODUCTION AND COSTABILITY ANALYSIS OF BIOACTIVE HYDROLYZATES OF WHEY PROTEIN

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***Abstract***

*Due to the fact that individual whey proteins have their own unique nutritional, functional and biological characteristics, the latest research in this area draws attention to the possibility of synthesizing a wide range of bioactive compounds derived from whey proteins. There are various ways to release bioactive peptides from precursor proteins or whey parent proteins. The paper will present the production of bioactive whey protein hydrolyzates (BHPS), which exhibit high antioxidant activity, and their economic profitability of production. Research is focused on the enzymatic and microbiological process of modifying whey proteins. Whey proteins can be easily modified under mild conditions of temperature and Ph values. For the purpose of this research, two scenarios were modeled: Scenario A, which involves the use of whey, and Scenario B, which involves the use of whey protein concentrate as a protein source. The entire process for both scenarios, which includes pre-treatment, whey protein modification and product separation, was modeled using the SuperPro Desinger program, which is equipped with a wide range of processes, and can be used for mathematical evaluation of the economic performance of the process.*

***Key words*:** *whey, protein, production of bioactive whey protein hydrolyzates*

## INTRODUCTION

Milk production as a part of livestock production has always had a significant place in the development of Serbian agriculture. The developed Strategies for the Development of Agriculture in Serbia at the macro and micro level indicate that there are available potentials that have not been used, both for the development of livestock production and milk production in the plains, hilly and mountain areas. However, due to the overall situation with Covid 19, there is a decrease in the number of cattle, as shown by the results presented in the Statistical Yearbook for 2021 [16], where the decrease is 3% compared to the previous two years (2019 and 2020), while for the ten-year average of 2011-2020, the total number of cattle is lower by 5.1%. With the decrease in the number of cattle, there is a decrease in the number of dairy cows, so that the production of milk and dairy products is reduced as well as the production of different types of cheese, and we know that investing in cheese production is very profitable more tha production of raw milk. In addition to earnings in cheese production, whey is also obtained as a by-product, which nowadays has a number of commercial applications [13].

Whey, which is produced in the process of cheese production, is a very important waste product of the dairy industry, due to its very rich nutritional composition, which is generated in very large quantities in milk processing processes [2, 3]. Whey contains more than half of the dry matter present in milk, including whey protein (20% of total protein) as the most attractive ingredient. Due to the wide range of bioactivity (antioxidant, antihypertensive, antitumor, hypolipidemic, antiviral and antibacterial) [11] and excellent functional properties (eg high solubility, water absorption, gelatinization and emulsifying capacity) [5] whey can be considered a very valuable by-product with wide possibilities of application in the food and pharmaceutical industry [7]. Therefore, they can be used as potential food ingredients and food supplements and as auxiliary drugs, where their bioactivity would help in the prevention and control of diseases [3].

Apart from the industrial production of the pure fraction of whey proteins, it is also possible to obtain bioactive protein substances by hydrolysis of whey proteins. Enzyme-controlled hydrolysis of whey proteins is one of the fastest, safest and most easily controlled techniques for obtaining bioactive peptides [10].

The main goal of research related to the production of bioactive whey peptides using the hydrolysis process is their commercialization, but the lack of a case study is a major obstacle in the development of this area. Therefore, the commercialization of bioactive whey protein hydrolysates requires comprehensive business case studies that include a clear understanding of the market situation, development of market strategy, analysis of technical work plan, management and staff, legal issues, preparation of financing plan, action plan, risk analysis and exit opportunities.

The basic information for any business plan for the production of industrial capacity includes an analysis of the economic feasibility of the process. Through the analysis of economic justification, it is necessary to accurately analyze the impact of key production parameters, such as production capacity, equipment costs, raw material costs, operating costs and selling price of products on total investment, repayment time and payback period [12, 9, 17]. There is a number of techniques that can be applied to assess the economic viability of a targeted process. Simulation software, such as SuperPro Designer [18], equipped with a wide range of processes, is a powerful tool that can be used to mathematically estimate the economic performance of a process. This process simulator shortens the time required for process development, allows comparison of alternative processes and provides an opportunity for interactive analysis of a large number of processes in a short time [14]. SuperPro Designer is widely used for simulation of industrial production of various bio-products and analysis of economic justification of such processes [4, 8, 15].

However, to our knowledge, analysis of economic feasibility of industrial production of bioactive whey protein hydrolysates has not been done yet. This shortcoming should be overcome in order to commercialize bioactive whey protein hydrolysates as very valuable products.

With that goal in mind, SuperPro Designer can be used to conduct an analysis of the economic feasibility of the production process of bioactive whey proteins at the industrial level and to establish fundamental knowledge related to the business plan of the production process of bioactive whey protein hydrolysates [1].

## MATERIALS AND METHODS

Whey protein concentrate (WPC, whey protein concentrate) with 80.0% (w/w) protein (DMV International, 5462 GE Veghel, The Netherlands) was used. The WPC solution was prepared as a 5.0% (w/w) suspension of WPC in water. The paper also used whey left over from cheese production (Imlek ad, Belgrade). The chemical composition of whey consists of: dry matter 9.8 ± 0.03% (w/v); proteins 2.6 ± 0.012% (w/v); fat 1.05 ± 0.08% (w/v) and lactose 5.6 ± 0.114% (w /v). Also, the bacterial strain *Lactobacillus rhamnosus* ATCC 7469 (American Culture Collection, ATCC, Rockville, USA) was used. The commercial enzyme Trypsin (porcine pancreas, EC 3.4.21.4) was purchased from Sigma-Aldrich Chemie GmbH (Steinheim, Germany).

Licensed software SuperPro Designer (as in my previous works) was used to test the possibility of using whey in various technological processes.

This program provides opportunities to find the optimal procedure for profitability analysis, and by adjusting the basic parameters it is possible to analyze and predict costs for many industrial processes.

## RESULTS AND DISCUSSIONS

### Description of the process model

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In order to convert whey protein into value-added products, microbiological and enzymatic transformation of whey protein was used to produce high quality bioactive whey protein hydrolysates (BHPS) that exhibit high antioxidant activity.

The research is focused on enzymatic and microbiological processes of whey protein modification. Whey proteins can be easily modified under mild temperature and pH conditions. The availability of different microorganisms and enzymes from different sources allows the manufacturer to choose the best option based on the desired quality of the final product. For the purpose of this research, two possible scenarios were modeled: Scenario A which involves the use of whey and Scenario B which involves the use of whey protein concentrate as a protein source. Both processes involve three processing steps: pre-treatment, whey protein modification and product isolation. Each step was optimized in a previous study by the author [5, 6]. A simplified flow diagram for the production process of 96% (w/w) bioactive whey protein hydrolyzate is shown in Figure 1.

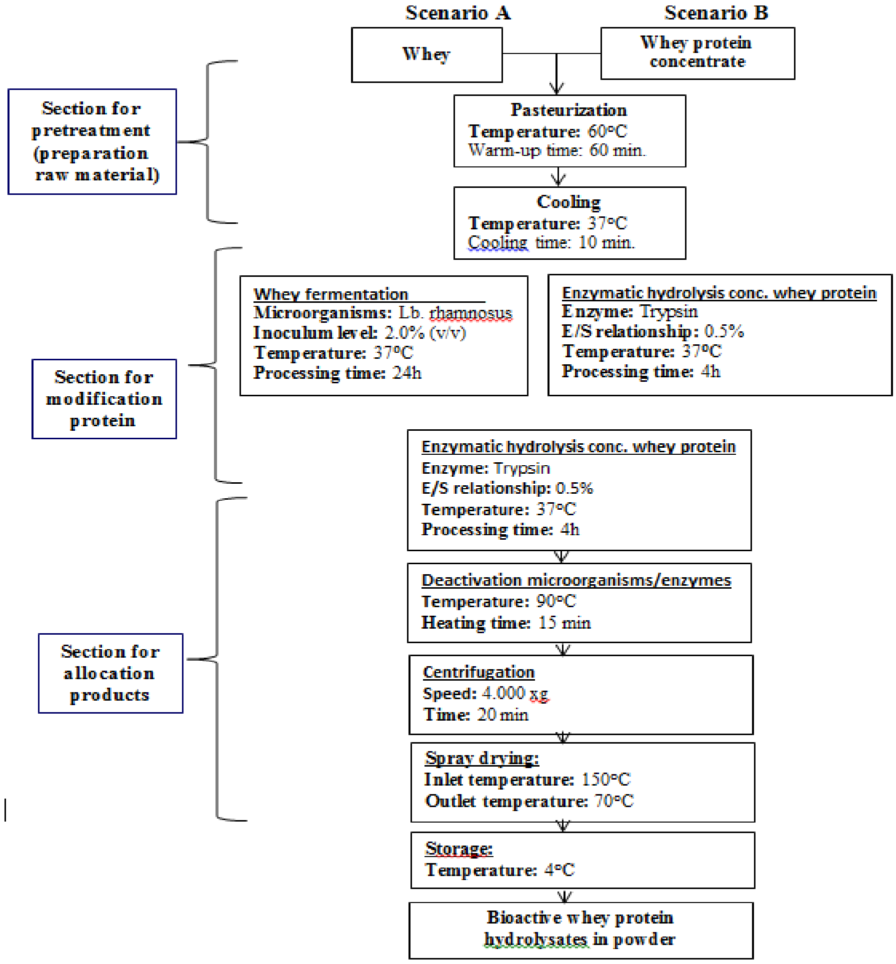


Fig. 1. Block flow diagram of the microbiological/enzymatic process, which is used for production bioactive HPS
Source: Slavica Arsić (2018), Analysis of the techno-economic justification of the exploitation of whey in Serbia. Doctoral dissertation/, University of Belgrade [1].

The entire process for both scenarios, involving pre-treatment, whey protein modification, and product isolation, was modeled using SuperPro Designer, and the flowcharts with the main process devices used in *Scenario* A and Scenario B are shown in Figures 2 and 3 [1].

In general, both processes begin with a step involving pre-treatment of raw materials. The purpose of the pre-treatment procedure is to prepare whey protein for the next step of modification.

To exclude the possibility of external contamination, the raw material was pasteurized at 60°C for 60 min using a HX-101 heat exchanger.

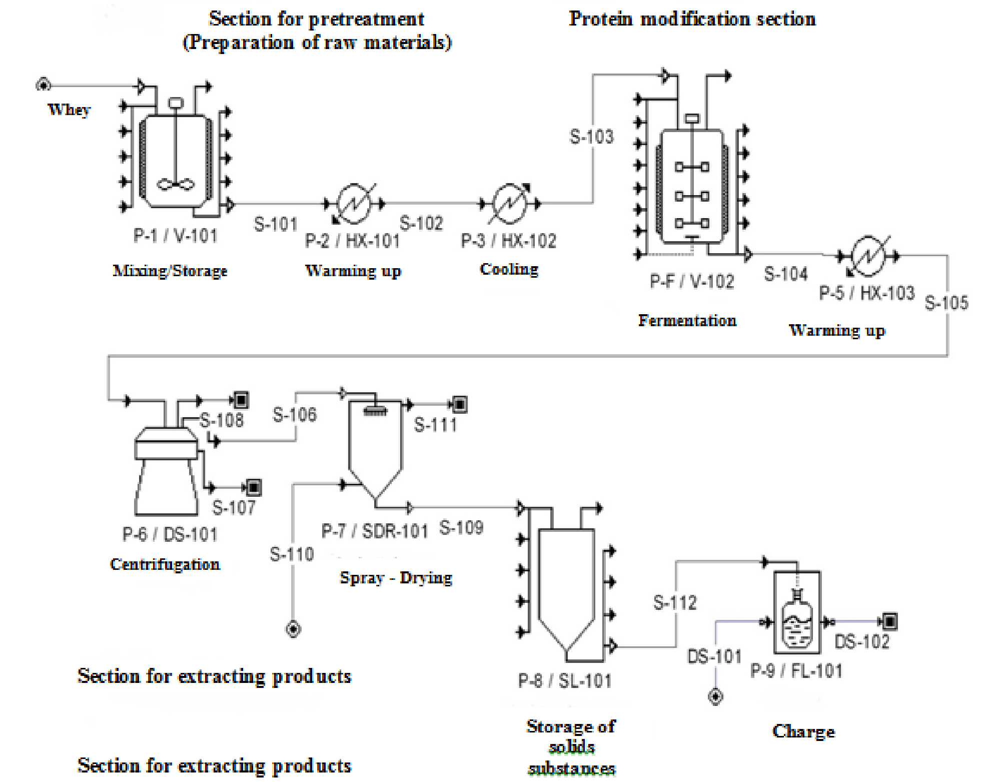


Fig. 2. Scheme of the process based on the use of raw whey (*Scenario* A)
Source: Slavica Arsić (2018), Analysis of the techno-economic justification of the exploitation of whey in Serbia. Doctoral dissertation/ University of Belgrade [1].

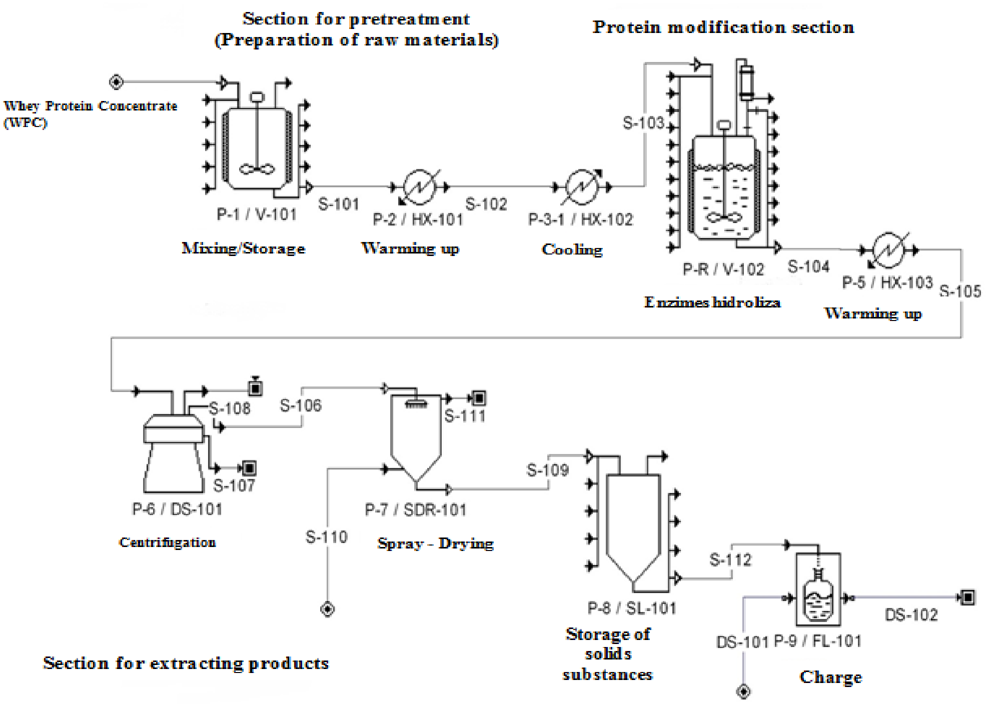


Fig. 3. Process scheme based on the use of whey protein concentrate (*Scenario* B)
Source: Slavica Arsić (2018), Analysis of the techno-economic justification of the exploitation of whey in Serbia. Doctoral dissertation/University of Belgrade [1].

After pasteurization, the mixture was cooled to 37°C using a HX-102 heat exchanger, and then transported to the section, i.e. the unit in which the protein modification will be performed.

The protein modification process in *Scenario* A involves a 24-hour fermentation process performed by the addition of 2.0% (v/v) inoculum of strain Lb. *rhamnosus* ATCC 7469 in a unit called P-F/V-102 (Figure 2). The protein modification process in *Scenario* B involves a 4-hour enzymatic hydrolysis process performed using 0.5% (w/w) of the commercial enzyme Trypsin in a unit called P-R/V-102 (Figure 3). Both processes were performed at a temperature of 37°C as optimal for the activity of microorganisms and enzymes. Both processes are interrupted by inactivation of the microorganism or enzyme at 90°C for 15 min using a HX-103 heat exchanger. After the protein modification process, the mixture is transported to a centrifuge unit (P-6/DS-101) to undergo the following steps involving product separation.

Liquid whey protein hydrolyzate is a highly perishable product due to its high water and protein content as a favorable substrate for bacterial growth. The powder form of whey protein hydrolyzate is a much more favorable form of this product, which is primarily lighter than the liquid form, which greatly facilitates its transport and enables longer storage time. In the product separation section, the bioactive whey protein hydrolysates were centrifuged and dried to produce BHPS in powder form.

Centrifugation performed at 4,000 xg for 20 minutes in a unit called P-6/DS-101 to separate the hydrolyzed suspension into two layers: a protein hydrolyzate solution at the top and a solid layer of non-hydrolyzed protein remaining at the bottom. After centrifugation, the whey protein hydrolyzate suspension was dried in a spray dryer, i. unit P-7/SDR-101 and stored at 4°C (unit P-8/SL-101) until the moment of packing. The end product of bioactive whey protein hydrolysates is a creamy white powder that is characterized by good water solubility and desired functionalities [1].

The basic capacity of 1,000 kg $h^{-1}$ processing of whey or whey protein concentrate results in the production of 8.1 t $year^{-1}$ hydrolyzate obtained by whey fermentation and 165.9 t $year^{-1}$ hydrolyzate obtained by hydrolysis of whey protein concentrate, with a protein content of 96% (w/w). The obtained products can be considered bioactive due to their high antioxidant activity, which confirms the efficiency of the production processes studied in this article.

Enzymatic modification of whey protein according to *Scenario B* reduces the total energy consumption of the production process. The total energy consumption in generation operations in *Scenario A* is 6.46 GW, while in *Scenario B* the total energy consumption is reduced to 5.86 GW. A decrease of 9.1% indicates a higher efficiency of Scenario *B*. The energy is mainly reduced due to the lower electricity demand in the reactor unit (P-R) used in the protein enzyme modification section. On the other hand, the use of enzymes increases the amount of bioactive whey protein hydrolyzate produced from 1.02 kg $h^{-1}$ as obtained by the whey fermentation process to 20.9 kg $h^{-1}$ as obtained by the enzymatic hydrolysis process. An increase of 95.1% increases the economic viability of the bioactive whey protein hydrolyzate production process according to *Scenario B*.

Table 1 shows the results of the economic analysis. For a plant with a base capacity of 1,000 kg $h^{-1}$, the total capital investment is $ 22,940,000 for *Scenario A* and $ 17,402,000 for *Scenario B*. Assuming that the selling price of the bioactive whey protein hydrolyzate is $ 20 $kg^{-1}$, the project has an internal return rate (IRR) of 17.73% for Scenario A and 230.55% for *Scenario B*.

Table 1. Summary of economic parameters for the analyzed scenarios A and B.

| **Parameter** | **Scenario A** | **Senario B** |
|---|---|---|
| Total investments ($) | 22,940,000 | 17,402,000 |
| Repayment period (years) | 3.06 | 0.09 |
| IRR after tax (%) | 17.73 | 230.55 |
| NPV na 7% ($ · $10^6$) | 25.38 | 1,635.5 |

Source: Results obtained by computer simulation in the program „*SuperPro Desinger*" [1].

The net present value (NPV) was approximately $ 25.38 million for *Scenario A* and $ 1,635.6 million for *Scenario B* (at a discount rate of 7%).

NPV is an indicator of return on investment, ie. an indicator of whether the investment can bring a profit. In this case, the NPV value is positive, which means that the investment provides an inflow of funds and therefore the project is economically viable and can be accepted and implemented.

Based on these results, the project that assumes Scenario B represents a much more attractive investment compared to *Scenario A.*

## CONCLUSIONS

Based on the results presented in this part of the research, enzymatic hydrolysis is the most suitable process for the production of bioactive whey protein hydrolysates. Industrial plant with a capacity of 1,000 kg $h^{-1}$, which is characterized by the following economic parameters: total capital investment of 17.40 million dollars; direct fixed capital expenditures of $ 15.98 million; annual operating costs of $ 9.14 million and a payback time of 0.09 years, allow the production of a bioactive whey protein hydrolyzate that could have a selling price of $ 20 $kg^{-1}$, which is significantly lower than the market price, so investing in this way of processing whey can be considered very cost effective.

The presented process offers an environmentally friendly and economically viable solution for the utilization of whey through its transformation into products of the second generation of whey protein-based products.

## ACKNOWLEDGEMENTS

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# COCOA FARMERS CREDIT DEFAULT AND ITS IMPLICATIONS FOR RURAL AGRICULTURAL FINANCING IN GHANA

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***Abstract***

*The role played by rural and community banks (RCBs) in financial intermediation in the cocoa sector is commendable, however, their full potential is not realized due to the high level of credit default by farmers. Among 95 credit takers for the 2018 to 2019 farming season, the study revealed that 68.4% of farmers defaulted, producing a loan recovery rate of 45.76% and default rate of 54.23%. The surveyed banks value the use of collateral security (47%) and fixed income guarantee (26%) as a prerequisite for accessing credit. Selected RCBs' predicaments of lending to farmers are the misappropriation of funds, high default rate, and high illiteracy rate. Averagely, farmers used 44.66% of the accessed credit amount for cocoa farming, and 55.34% on non-farm-related activities, indicating the misappropriation of funds. Defaulters' reason for delinquency is classified into; causes due to the borrower (24.60%), causes due to the lender (32.04%), and causes due to nature (43.36%). Moreover, RCBs' perception of the causes of loan delinquency includes misappropriation of funds, unwillingness to pay, risk in cocoa farming, and high-interest rate. Finally, probit model results indicated that farmers' repayment abilities were positively influenced by their engagement in secondary occupation, attainment of formal education, and loan terms, and negatively influenced by household size, loan amount received, interest rate, and distance to rural banks. The study recommends RCBs to enact stringent borrowing policies aimed at reducing loan delinquency among cocoa farmers in Ghana.*

***Key words***: *credit default, cocoa, rural and community bank, smallholders*

## INTRODUCTION

According to [14], almost 7.4 million Ghanaians depend on cocoa for sustenance. Apart from the 50 countries in the inter-tropical zones reported to be highly engaged in cocoa bean cultivation, Indonesia (13.5%), Ghana (20.7%), and Cote d'Ivoire (39%) have dominated total world production. Approximately, 70% of the world's total cocoa production originates from West Africa [1, 30, 40] and this region is seriously confronted with a 3% annual decline in production. Currently, Ghana produces an average of 400 kgha$^{-1}$ which is almost 50% below the world's highest producer, Cote d'Ivoire, with an average output of 800 kgha$^{-1}$ [40, 24, 10]. The lack of institutional credit has been identified as the main factor affecting cocoa farmers in Ghana. Globally, studies on the importance of credit assert that the inaccessibility of credit by rural farmers has retarded the progress of agriculture growth [28, 16]. Significant literature exists on the positive impact of credit in improving the household income of small business holdings, and the productivity of smallholder farmers [32, 17, 9, 11]. Due to the inherent credit problems facing cocoa farmers in Ghana, rural and community banks (RCBs) were established in the cocoa-growing regions and were mandated to allocate 50% of their credit portfolio to farmers. Nevertheless, the positive benefits of credits have been cut short by many inherent problems existing in the rural financial system. Among such problems is the issue of credit default prevalent among rural borrowers in many financial institutions globally. The definition of credit default is not based on the kind and proper use of the credit but rather on the untimeliness of meeting the repayment schedule mandated by the credit institution. The solvency of rural banks in the country is the number one aim of their governing body- Apex Bank and the Bank of Ghana. Though several factors may be responsible, it is the impact of credit default that has caused many farmer credit schemes to be stopped in Africa. In this regard, several objectives of the credit program are not achieved due to farmers spending too little money on the farm or diverting the majority to non-agricultural-related activities. The practice of diverting agricultural credit to other uses is popularly referred to as credit fungibility. As asserted by [34, 35], credit fungibility exists at all levels of the rural financial system- the culprits are farmers, rural banks, and central banks. Several factors have been associated with the cause of credit default among rural farmers [31, 3, 15]. It is a known fact that many credit programs are well-financed by governments such that disbursing institutions are tasked with satisfying the needs of farmers under a set of political directives rather than considering farmers' repayment history. In Ghana, especially in cocoa-growing communities, the resultant effect of credit default is the current downward trend achieved in the agricultural sector, and the subsequent increase in rural poverty among farming communities because RCBs are reluctant to offer credit to the farmers. Best to our knowledge, no primary study exists on the level of credit default among Ghanaian cocoa farmers utilizing RCBs credits. Many studies evaluated the importance of credit on farmers' productivity, while others determined the causes of credit default in the agricultural sector in general. A plethora of evidence exists on the importance of rural banks' credits for supporting rural cocoa farmers, but nothing is available on the problems rural banks have to encounter before redeeming credit already disbursed. Issues such as the use of credit, farming constraints, and awareness to increase government support for rural farmers have been the centerpiece of many publications. With the surge in the amount of rural credit disbursed, it is pertinent to understand the circumstances surrounding the credit repayment abilities of farmers in cocoa-growing regions in Ghana, since this will adequately inform the government, Bank of Ghana, donor agencies, and the Apex Bank about improving financial incentives to the sector. Finally, the output of this study will serve as a blueprint for RCBs and other financial institutions (operating farmer-credit schemes) in developing comprehensive credit monitoring tools that seek to minimize the rate of credit default among all groups of farmers.

## MATERIALS AND METHODS

### Study Area

The study was conducted in the Bodi District, one of the nine districts in the Western North Region in Ghana. It is located between latitude 6°6' N and 7°0' N, and longitude 2°40'W and 3°, 15W. The district covers an estimated surface area of 678.1 kilometers squares. It has a population of 65,748, and a population density of 97 kilometers square. Sefwi-Bodi is the district capital. The district forms part of the country's wet semi-equatorial climatic zone. It is characterized by two rainfall patterns with mean annual figures between 1,260-2,000mm. Regarding economic activity, 84% of the population above the age of 15 years are actively engaged in agriculture, forestry, and fishery. The remaining 5.5% are engaged in service and sales, and 4.3% practice craft and trade-related works. Subsistence agriculture is predominant in the district and serves as means of survival during the mean lean season. Cocoa is grown in almost all communities in the district contributing 15% of the total cocoa output in the region. Agricultural activities in the district are supervised by the district director of agriculture legitimately appointed by the Ministry of Food and Agriculture (MOFA). Under the auspices of MOFA, the agricultural communities in the district are classified as operational areas for ease of monitoring and evaluation of government programs. Currently, there are seven operational areas engaged in intensive cocoa cultivation in the district. The district has two well-functioning rural and community banks namely Bia Torya Community Bank Limited and Sefwiman Rural Bank Limited. These banks serve as a source of financial aid to all categories of farmers operating in the district. Famers unable to secure farming credit from the two RCBs have to rely on local money lenders, family and friends, personal income, and non-governmental organizations for sponsoring their farming activities.

**Data Sources**

The study used secondary data for cocoa farmers with access to institutional credit from the two rural banks in the district. The credit takers list was provided by the rural banks containing credit disbursed to cocoa farmers for the 2018 to 2019 farming season. The list includes farmers' details such as telephone numbers, amount of loan taken, loan repayment history, etc. Table 1 below indicates farmer distribution across operational areas concerning the credit secured from the two RCBs. Moreover, 51 and 44 farmers representing 53%, and 47% secured credit from the two selected RCBs.

Table 1. Rural Bank Credit Takers

| Rural Bank | Operational Area | No. of Farmers | Percentage (%) | Cumulative % |
|---|---|---|---|---|
| Bia Torya Community Bank Ltd. | Bodi | 15 | 29.4 | 29.4 |
| | Afere | 8 | 15.6 | 45.0 |
| | Suiano | 7 | 13.8 | 58.8 |
| | Kwafuka | 9 | 17.6 | 76.4 |
| | Amoaya | 12 | 23.6 | 100 |
| Sefwiman Rural Bank Ltd. | Bodi | 17 | 38.6 | 38.6 |
| | Datano | 3 | 6.8 | 45.4 |
| | Afere | 11 | 25.0 | 70.4 |
| | Ahibenso | 8 | 18.2 | 88.6 |
| | Amoaya | 5 | 11.4 | 100 |

Source: Author's survey data.

**Data Collection Procedure**

With the help of credit officers, selected farmers on the credit takers list were contacted by telephone numbers to seek their concerns and willingness to participate in the study. Few farmers were not happy about the bank's disclosure of their confidential information to us but later changed their position to participate after several hours of active engagement and explanations. A total of 95 credit takers from seven operational areas participated in the study. Cross-sectional data was collected from credit takers and RCBs using structured questionnaires. The questionnaires were pretested on 10 participants to correct for order bias and possible misinterpretation of the questions. Five data enumerators (MOFA's extension agents) were trained about the procedure, particularly in considering the existing language barriers since the majority of farmers are illiterates. The explanatory variables were classified as socioeconomic factors, farming characteristics, and institutional factors. Information sourced includes farmers' credit use, RCBs prerequisites before granting credit, banks' predicaments of lending to cocoa farmers, credit recovery rate, and banks' perception of the causes of loan default. The research was conducted from 3rd to 28th November 2019.

**Model Specification**

The study adopted the probit model because of its ability to solve the problem of heteroscedasticity and the dependent variable can be in binary form and mutually exclusive. As adopted by [26], the probit model adopted is specified as:

$$P_i = P(y_i^* < y_i) \quad (1)$$

$$P_i = P\left(y_i^* < \beta_0 + \beta_{ij} x_{ij}\right) = f(y_i) \quad (2)$$

$$P_i = f(y_i) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{zi} e \frac{s^2}{2} \, ds \quad (3)$$

where:

$P_i$ represents the choice of a particular farmer or the probability that a farmer will default his loan or non-default. ***S*** is a random variable normally distributed with a meanzero and unit variance $y_i$ is the binary dependent variable. Also, $y_i^*$ is the threshold value of the dependent variable. The estimate of index $Z_i$, the inverse of the cumulative function is represented as:

$$y_i = F^{-1}(P_i) = \beta_0 + \beta_i x_i + \mu_1 \quad (4)$$

The $\beta_0$ and $\beta_i$ of the probit model gives inadequate information about the impact of changes in the independent variable and the probability of default. Hence the effect of each independent variable on the likelihood that a farmer will default on a loan is given as:

$$\frac{\partial P_i}{\partial x_{ij}} = \beta_i * f(Z_i) \qquad (5)$$

Where $P_i$ is the mean dependent variable whose value is given in the probit as:

$$f(Z_i) = F^{-1}(P_i) \quad (6)$$

Similar to the study of [21, 29], socio-economic attributes were identified and hypothesis constructed regarding farmers' loan default. The final model is represented as:

$$Y=\beta_0+\beta_1 gen+\beta_2 age+\beta_3 hsesize+\beta_4 educ+\beta_5 offIncome+\beta_6 lamount+\beta_7 lterm+\beta_8 dist+\beta_9 fmsize+\beta_{10} disas+\beta_{11} fmage+\beta_{12} inrate+e_i \quad (7)$$

where:

$Y$ is the dependent variable of Loan default =1, Non-default = 0, β values are coefficients to be estimated, ($i$ =1, 2….,12), $\beta_0$ is the intercept and $e_i$ is the error term. gen denotes gender of farmer, age denotes the age of cocoa farmer, hsesize denotes family size, educ denotes educational status of farmer, offincome denotes off-farm income activities, lamount denotes loan amount, lterm denotes loan term or repayment period, dist denotes distance from farmer's house to the rural bank, fmsize denotes farm size, disas denotes any form of disaster that has affected the farm, fmage denotes age of cocoa farm trees, inrate denotes interest rate charged by rural banks on loans. The five-point Likert scale was used to determine RCB's predicament of lending to farmers, as well as bank's perception of the causes of loan default.

Descriptive statistics were used for determining credit recovery rate, causes of credit delinquency from farmers' perspective, and RCBs prerequisites for credit access, whilst multiple response analysis was adopted for assessing farmers' credit use. Table 2 show the priori expectations which indicates the possible direction of influence of these variables on the outcome variable. The positive determinants or signs are perceived to improve the credit repayment abilities of farmers while the negatives reduce the probability of repayment consequently causing a default.

Table 2. A Priori Expectations of Explanatory Variables.

| Explanatory Variables | Short Description | Expectation |
|---|---|---|
| Gender | Sex of farmer | + |
| Age of farmer | Age of farmer | + |
| Household size | Size of family | +/- |
| Education | Education level of farmer | + |
| Off-farm Income | A farmer engaged in off-farm economic activity | +/- |
| Distance to bank | Distance from farmers houses to the rural bank | + |
| Farm Size | Size of farm | + |
| Age of farm | Age of the trees on the farm | +/- |
| Disaster | Any form of farm disaster | - |
| Credit amount received | Amount of money received from the bank | + |
| Credit terms | Credit repayment period | +/- |
| Interest rate | Interest rate charged on loans | +/- |

Source: Author's survey data.

## RESULTS AND DISCUSSIONS

### Descriptive Statistics

The list of variables used is presented in Table 3. The mean cocoa yield for the district was 305.23 kg/ha indicating a lower production potential for farmers. This result is inconsistent with the findings of [10] that the mean yield of most Ghanaian farms is approximated at 400 $kgha^{-1}$.

Table 3. Descriptive statistics of sampled farmers

| Description of Variables | Mean | Std. Dev. | Min. | Max. |
|---|---|---|---|---|
| ***Dependent variables*** | | | | |
| Cocoa yield ($kgha^{-1}$) | 305.23 | 35.32 | 102.21 | 410.23 |
| Credit default (1=yes, 0=no) | 0.65 | 0.21 | 0.00 | 1.00 |
| ***Explanatory variables*** | | | | |
| ***Socio-economic characteristics*** | | | | |
| Gender (1=male, 0=female) | 0.90 | 0.23 | 0.00 | 1.00 |
| Age (years) | 37.5 | 2.13 | 21.00 | 59.00 |
| Household size (count) | 4.01 | 0.12 | 3.00 | 8.00 |
| Education (1=yes, 0=no) | 0.37 | 0.12 | 0.00 | 1.00 |
| Off-farm income (1=yes, 0=no) | 0.90 | 0.23 | 0.00 | 1.00 |
| Distance to bank (km) | 13.50 | 3.70 | 2.54 | 28.23 |
| ***Farming characteristics*** | | | | |
| Farm size (ha) | 2.43 | 0.18 | 1.79 | 6.45 |
| Age of farm (years) | 11.05 | 1.32 | 5.05 | 20.07 |
| Disaster (1=yes, 0=no) | 0.74 | 0.21 | 0.00 | 1.00 |
| ***Institutional factors*** | | | | |
| Credit amount received (Gh¢) | 2,000.00 | 193.43 | 500.00 | 3,500.00 |
| Credit terms (months) | 8.00 | 1.02 | 3.00 | 13.00 |
| Interest rate (%) | 25.00 | 7.54 | 15.00 | 30.00 |

Source: Author's survey data.

From the table, 90% of the sample were males, the credit default rate was 65% suggesting that majority of credit-takers have defaulted. [21, 7] reported more than 50% loan defaults among agriculture credit recipients. The mean age of farmers was 37.5 years, while the minimum and maximum of 21 and 59 years respectively. The mean household size of 4 and a maximum size of 8 people attest to the fact that the majority of farmers have larger family sizes which are sometimes advantageous in substituting for paid farm labor. Formal education is needed for reading and interpreting basic prescriptions, performing banking transactions, and methodologies to help farmers in areas such as loan applications, chemical applications, equipment manipulation, and farm record keeping [22]. Only 37% of farmers having access to basic education contradicts the previous findings of [8]. Besides cocoa farming, 90% of farmers' were engaged in secondary occupations. This was important because of its sustainability during the lean season especially when the income of most farmers plummets. The mean distance from a farmer's farm to rural banks premises was 13.50 km, with a maximum of 28.23km, all indicating how far most rural farmers are from the banking institutions. Adversely, this has affected many farming decisions such as attending field demonstrations, applying for rural banks' credit schemes, and active engagement in farmer registrations needed for budgetary allocation for subsidy programs. The mean farm size was 2.43 ha supporting the finding of [6] that the majority of Ghanaian cocoa farmers are operating on a small scale basis with land sizes less than 3 ha. The age of farm which intrinsically represents the age of trees on the farm was 11.05 years indicating the majority of the farmers were operating older farms. As high as 74% of farmers reported the incidence of pests and diseases, bush fires, and drought as major problems in the region. Participants in the credit program received a mean amount of 2,000 Gh¢, with a minimum and maximum of 500 Gh¢ and 3,500 Gh¢ to be repaid over an average of 5 months period. Finally, the average interest rate charged on most loans by rural banks was 25% per annum and has a maximum of 30% per annum. This is critical for the survival of most farming enterprises because higher interest rates in the face of high farming risks and inflation encourage unprecedented loan defaults.

**Rural Banks Pre-requisites for Credit Access**

The information obtained from the RCBs concerning what they value most before granting loans to farmers is displayed in Table 4. The credit appraisal systems in most rural banks in Ghana have evolved over the years, thus introducing several structural and security measures that seek to reduce the number of bad loans that banks accumulate over the years. It is deemed necessary for all loan applicants to fully satisfy application requirements before being considered for further processing and subsequent granting of loans.

Table 4. Important RCBs Considerations in Granting Credits

| Factors | Percentage (%) | No. of Banks |
|---|---|---|
| 1. Collateral security | 47.0 | 2 |
| 2. Average deposit required | 11.0 | 2 |
| 3. Fixed income guarantees | 26.0 | 2 |
| 4. Up-to-date farm records | 3.0 | 2 |
| 5. Size of loan facility | 9.0 | 2 |
| 6. Duration of loan facility | 4.0 | 2 |

Source: Author's survey data.

The most important factors considered by the banks before granting loans to farmers were ranked in the order 1 being least important, 2 important, 3 very important, and 4 extremely important. From the results, banks consider collateral security (47%) as the single extremely important factor before granting loans. Consistent with this finding is that of [28, 19, 20] which comprehensively deal with the issues of collateral security used as the most important prerequisites by financial institutions. An in-depth discussion with the selected bank staff revealed some intriguing information about the kind of collateral security demanded. Fixed assets such as registered lands, both private and commercial buildings, and registered company assets are the most preferred because of their high commercial values. The reason is simply to liquidate these productive asserts in times of loan default. The most important observation from this study is that while rural banks regard collateral security as the most important evaluation criteria for granting loans, rural farmers also think it's the most difficult condition they can satisfy before accessing loans hence, it derails their initial attempt to apply for rural banks loans. The study also discovered that average deposits by farmers can be used as determining factor to grant loans. This condition for accessing loans might be introduced due to the inability of rural farmers to provide collateral security. Banks have designed it as a substitute for collateral security, and also to encourage regular savings habits among rural farmers. Irrespective of how banks have lessened the burden of collateral security, regular savings by farmers cannot be possible because they have to stay poor for several months before harvest. Otherwise, to satisfy this condition, farmers must forcibly liquidate their assets which ultimately results in higher household risks. Also, the idea of regular savings demanded will not be feasible in the context of the Ghanaian banking sector where the inflation rate is always higher than the interest rates of all banks' savings. Fixed income guarantee was the second preferred condition borrowers must satisfy before assessing credits. Banks needed farmers to be earning regular income certified by employers where loan deductions can be easily made or the appropriate institution can be contacted in terms of farmers' breach of contract. This does not play well with farmers because most are self-employed and lack fixed incomes in the sense that the only time of receiving regular earnings is after the harvesting period. The size of the loan facility (9%) is also considered by selected rural banks before approval, however, interviewed bank staff revealed that this criterion is used for huge sums of monies mostly requested by bigger business individuals. Duration of loan facilities was also mentioned, however, 4% of rural banks claimed it is not a priority but they sometimes must adapt it, especially for high-risk borrowers and a large sum of monies.

**Rural Banks' Predicaments in Supporting Rural Cocoa Farmers**

The main idea of establishing rural banks in many farming communities in Ghana is to provide financial incentives to farmers which will consequently contribute to production efficiency. However, many factors have derailed the positive working condition of rural banks in the country. In determining the most influential factors framing rural banks from further offering credit to cocoa farmers, we relied on a five-point Likert scale which is considered an interval scale. The variables were scored in the range; 1=strongly disagree, 2= disagree, 3=neutral, 4=agree, and 5=strongly agree.

Table 5. Rural Banks' Predicaments of Issuing Credits to Farmers

| Variables | N | Minimum | Maximum | Mean | Std. Deviation | Skewness |
|---|---|---|---|---|---|---|
| Misappropriation of funds | 10 | 4.00 | 5.00 | 4.60 | 0.516 | -0.484 |
| High default rate | 10 | 4.00 | 5.00 | 4.60 | 0.516 | -0.484 |
| High illiteracy rate | 10 | 4.00 | 5.00 | 4.30 | 0.483 | 1.035 |
| Lack of collateral security | 10 | 1.00 | 5.00 | 3.90 | 1.595 | -1.441 |
| Risk in cocoa farming | 10 | 2.00 | 5.00 | 3.80 | 0.918 | -0.601 |
| Death of borrower | 10 | 2.00 | 4.00 | 2.90 | 0.737 | 0.166 |

Source: Author’s survey data.

While the generated mean is considered to be very significant, the criteria for evaluation stipulate that from 1 to 1.8 suggests strongly disagree, 1.81 to 2.60 suggests disagree, 2.61 to 3.40 holds for neutral, 3.41 to 4.20 for agree, and from 4.21 to 5 simply implies strongly agree. The results from Table 5 suggest that majority of the bank respondents strongly agree that misappropriation of funds and high default rate among farmers is the critical factor inhibiting them from financially supporting the agricultural sector. Misappropriation of funds is very common among rural farmers. The majority of farmers intentionally divert agricultural credit to non-agricultural activities such as buying commercial vehicles for business, building houses for renting, organizing a funeral for dead relatives, etc. However, without properly evaluating these investment options, many farmers run into serious debts which consequently result in loan defaults. Many studies have also reported the instances of farmers diverting agricultural loans to non-agricultural uses and its effect on their loan repayments abilities [28, 19, 20]. The high illiteracy rate among farmers having a mean value of 4.30 suggests that banks strongly agree to it as a major problem whenever dealing with farmers. All financial transactions are executed formally hence requiring all parties involved to write and understand the contract terms and conditions before appending their signatures. Sadly, the majority of cocoa farms are illiterate and can hardly understand the conditions explained to them. The issue of collateral security with a mean of 3.90 agreed as another potential factor many farmers grapple with upon being requested by many banks. Farmers have grieved with this requirement but nothing can be done about it since rural banks have to find suitable means to recover disbursed loans in times of default. Banks agree to the fact that cocoa farming is a risky business that ultimately depends on several factors besides farmers’ accessibility to suitable farming credits. Surveyed banks were neutral about the death of borrowers since it was a non-recurring problem.

**Credit Recipients Credit Use**

The proper use of credit will eventually reflect the repayment abilities of farmers. Many financial institutions have gone defunct due to the inability of rural farmers’ to fulfill their loan repayment obligations. Table 4 indicates the uses of loans by farmers from the selected RCBs. From the results, 51.04 % and 38.3% of funds received from the two RCBs were used for farming purposes. Averagely, the selected farmers invested 44.6% of their funds in cocoa cultivating activities. Non-farm uses of credit for the 95 recipients which include spending on school fees, trade expansion, and building of houses recorded a mean value of 25.02% of the credit amount received. The use of loans for the purchase of items for consumption, and durable goods accounted for 25.43% and 35.22% of the total amount borrowed from the RCBs. The purchase of food items constituted a larger proposition of this spending. The findings suggest that some farmers are abusing agricultural credit, and further support the assertion that although most entrepreneurs state lack of finance as a hurdle to farm set-up and commercialization, it is not a grantee that they will use it productively when granted [39, 4]. The present findings on the issue of credit default among farmers are in line with these studies [31, 3].

Table 6. Use of Credit from Rural Banks

| Credit Use | Bia Torya Bank | | Sefwiman Rural Bank | | Grand Total | |
|---|---|---|---|---|---|---|
| | **Number of farmers reporting use** | **Percent of funds** | **Number of farmers reporting use** | **Percent of funds** | **Number of farmers reporting use** | **Percent of funds (Mean)** |
| **Farm Use** | | | | | | |
| Hired Labour | 37 | 21.7 | 22 | 14.8 | 59 | 18.25 |
| Farmland | 21 | 1.09 | 12 | 0.82 | 33 | 0.95 |
| Seed/seedling | 14 | 9.06 | 15 | 2.54 | 29 | 5.80 |
| Farm Implement | 17 | 7.34 | 11 | 8.93 | 28 | 8.14 |
| Fertilizer | 47 | 9.54 | 17 | 9.65 | 64 | 9.59 |
| Others | 9 | 2.31 | 11 | 1.54 | 20 | 1.93 |
| Total | | **51.04** | | **38.28** | | **44.66** |
| **Non-Farm Use** | | | | | | |
| School fees | 7 | 4.71 | 6 | 3.43 | 13 | 4.07 |
| Trade expansion | 5 | 9.35 | 13 | 12.43 | 18 | 10.89 |
| Building / Repairing house | 8 | 7.21 | 6 | 7.81 | 14 | 7.51 |
| As loans to relatives | 3 | 0.78 | 2 | 0.98 | 5 | 0.88 |
| As loans to farmers | 2 | 0.94 | 2 | 0.91 | 4 | 0.93 |
| Others | 2 | 0.54 | 4 | 0.94 | 6 | 0.74 |
| Total | | **23.53** | | **26.50** | | **25.02** |
| **Consumption/ Durable Goods** | | | | | | |
| Food | 51 | 15.73 | 44 | 21.45 | 95 | 18.59 |
| Clothes | 9 | 0.91 | 12 | 0.72 | 21 | 0.82 |
| Festivals/ Ceremonies | 15 | 2.34 | 11 | 4.75 | 26 | 3.54 |
| Durable goods | 13 | 3.20 | 29 | 4.21 | 42 | 3.71 |
| Hospital | 29 | 1.74 | 11 | 2.14 | 40 | 1.94 |
| Dowries | 3 | 0.95 | 5 | 1.59 | 8 | 1.27 |
| Others | 2 | 0.56 | 3 | 0.36 | 5 | 0.45 |
| Total | | **25.43** | | **35.22** | | **30.32** |

Source: Author's survey data.

## Loan Delinquency

The inability of farmers to meet the repayment deadline requested by RCBs usually results in farmers' loan defaults. The mean amount of loan received by the recipients was 2,000 Ghana cedis (GH¢), with a minimum and maximum amount of 500 and 3,500 Gh¢ respectively. In literature, loan delinquency which is synonymous with default is accounted for as (1) the number of people who defaulted and (2) the amount of credit delinquent. It was discovered that out of 95 credit takers, 65 were delinquent in repayment, which produces a delinquency rate of 68.4%. In total, a sum of 850,000 Gh¢ was loaned out to cocoa farmers by the two rural banks. From this amount, only 389,000 Gh¢ was recovered which gives a repayment/ recovery rate of 45.76% and a delinquency rate of 54.23%. The causes of delinquency then become an important topic in this study and must be unveiled. The causes of credit default are mostly attributed to smallholder farmers, however, since all categories of farmers can default, default cannot be assumed to be a function of poverty. If it were to be, then, most financial institutions would have found the solution and achieved a 100% recovery rate.

Table 7. Causes of Credit Delinquency (n=62)

| **Causes of Delinquency** | **Percentage (%)** |
|---|---|
| ***Causes due to the borrower*** | |
| I don't have a feeling of obligation to repay | 0.45 |
| Unwillingness to liquidate farm assets to meet repayment obligation | 15.90 |
| Credit corporation is government-owned, so no need to repay its loan | 0.95 |
| My share of the national cake | 1.75 |
| Credit corporation's repayment could be delayed until I have money to repay | 4.65 |
| Non-serious attitude of some group members/chairman | 0.90 |
| Sub-total | **24.60** |
| ***Causes due to the lender*** | |
| Unavailability of the credit package input at the season when the loan was approved | 2.78 |
| Credit package input arrived too late for use at the season when the loan was approved | 5.74 |
| Credit corporation officials usually arrive without prior notification to collect the loan repayment | 3.87 |
| Credit corporation officials promised to buy farm produce resulting from the use of credit but failed | 2.45 |
| Credit approval delayed | 6.75 |
| Improper supervisor of loans use by bank staff | 10.45 |
| Sub-total | **32.04** |
| ***Causes due to nature*** | |
| Low returns on investment made with the loan | 2.45 |
| Low crop yield due to bad weather | 12.20 |
| The outbreak of disease on the farm | 11.75 |
| Farmer's sickness during the farming season | 0.90 |
| Financial problems in the family | 5.54 |
| Bush fire due to extreme temperature regimes | 9.90 |
| Litigation on the land due to government projects | 0.62 |
| Sub-total | **43.36** |

Source: Author's survey data.

Since the willingness to pay and the attitude of borrowers are key determinants of their repayment abilities, trying to find a single reason for loan default becomes difficult. Following the study of [31] and in table 7, the causes of delinquency are classified into three. The first, delinquency resulting from the farmer's activity termed as "causes due to the borrower" was 24.60 %. Issues such as farmers' unwillingness to liquid their farm assets to repay loans during default was the highest (15.90%), forcing a delay in repayment periods given by banks (4.65%), and share of national cake (1.75%). The second which is a cause emanating from the activities of the lender termed "causes due to lender" was 32.04%. The majority (10.45%) of farmers asserted that rural banks were operating credit schemes with weak monitoring systems causing loan diversion among farmers. The delay in approving credits due to bureaucratic procedures was another problem faced by farmers. This has caused a delay in purchasing farming inputs resulting in the late application of fertilizers, insecticides, and weedicides ultimately contributing to lower yields. The third which is beyond farmers' control because it's a cause by nature was 43.36%. Farming-related problems such as bush fires, uncertain weather conditions, litigation cases, and low return on investment were among the topmost concerns. Studies exist on the effects of pests and diseases causing annual cocoa yields losses in Ghana [12, 5]; the importance of good weather in agriculture systems [33]; delays in loan repayments by farmers [41, 23]; lack of farming credits [38]; and delays and bureaucratic processes involved in loan processing [21].

**RCBs' Perception of the Causes of Loan Delinquency**

Table 8 critically examines the most influential causes of loan default among farmers from RCB's perspective. Rural banks operate within a constrained framework of budgetary allocation hence, a large amount of non-performing loans will automatically render the bank defunct. Nevertheless, many RCBs have stringent lending policies that seek to continuously identify and eliminate the delinquent behavior of farmers. In determining the most influential factors considered by RCBs in causing loan default rates among farmers, we relied on a five-point Likert scale. The variables were scored in the range; 1=strongly disagree, 2= disagree, 3=neutral, 4=agree, and 5=strongly agree.

Table 8. Banks' Perception of the Causes of Loan Default

| Variables | N | Minimum | Maximum | Mean | Std. Dev. | Skewness |
|---|---|---|---|---|---|---|
| Death of borrower | 2 | 2.00 | 5.00 | 3.40 | 0.96 | -0.11 |
| Misappropriation of funds | 2 | 4.00 | 5.00 | 4.70 | 0.48 | -1.03 |
| Unwillingness to pay | 2 | 4.00 | 5.00 | 4.10 | 0.31 | 3.16 |
| Risk in cocoa farming | 2 | 3.00 | 5.00 | 4.20 | 0.63 | -0.13 |
| High interest rate | 2 | 4.00 | 5.00 | 4.60 | 0.51 | -0.48 |
| Delay in loan processing | 2 | 1.00 | 4.00 | 2.40 | 1.07 | 0.32 |
| Inadequate loan amount | 2 | 1.00 | 4.00 | 2.60 | 1.17 | -0.04 |
| Excessive loan amount | 2 | 1.00 | 2.00 | 1.50 | 0.52 | 0.00 |

Source: Author's survey data.

While the generated mean is considered to be very significant, the criteria for evaluation stipulate that from 1 to 1.8 suggests strongly disagree, 1.81 to 2.60 suggests disagree, 2.61 to 3.40 holds for neutral, 3.41 to 4.20 for agree, and from 4.21 to 5 implies strongly agree. From the empirical results, the misappropriation of funds by farmers with a mean of 4.70 was selected as the most influential cause of the sprawling loan default among farmers. According to [37, 18], the intentional diversion of loans to non-productive activities which preclude borrowers' chances of loan repayments needs to be addressed by all financial institutions before granting loans. High-interest rates charged on loans with a mean of 4.60 indicate a strong agreement. Currently, the 30% per annum interest rate charged by RCBs on most agricultural loans subjects farmers to poverty forcing them to liquidate their productive assets to settle their debts. Moreover, the issue of high-interest rates charged on loans causing major repayment problems for borrowers has been reported in many studies [41, 23]. Risk in cocoa farming with a mean of 4.20 suggests an agreement by banks for its causal effect on loan default among farmers. [13, 27] have attested to this finding and recommend proper insurance policies be enacted for farmers. The unwillingness on the part of some farmers to repay loans (4.10) is another critical factor hindering the active financial performance of RCBs in rural communities. Rural farmers are of the view that RCBs sponsorship directly emerges from the Bank of Ghana, hence, without fulfilling their loan obligations will be taken as a piece of cake. Bank staff held a neutral view on the death of loan takers leading to default because they suggested that living relatives can sell the deceased's farm stocks after harvest to settle any outstanding loans. Delay in loan processing and the inadequate loan amount was disagreed to be causing agent for loan default. Moreover, banks strongly disagree with giving rural farmers excessive loans causing significant repayment problems.

**Factors Influencing Farmers' Credit Repayment**

Since personal characteristics, household, economic situations, and other relevant farming factors vary, the 95 loan takers will not be expected to behave in similar ways when the issue of repayment is at stake. From Table 9, model diagnostics indicate the coefficient of determination to be 0.670. Practically suggests that 67% of the variations in the loan repayment abilities of farmers are appropriately represented by the explanatory variables used.

Table 9. Determinants of Loan Repayment of Farmers

| Variable | Coefficient | Standard errors | Z-stats. |
|---|---|---|---|
| Constant | -2.157*** | 0.289 | -7.435 |
| Age of household head | -0.143 | 0.114 | -1.254 |
| Gender of household head | 0.112 | 0.321 | 0.348 |
| Secondary occupation | 0.241*** | 0.017 | 14.176 |
| Farm age | 0.014 | 0.132 | 0.106 |
| Formal education | 0.046** | 0.012 | 3.433 |
| Household size | -0.214* | 0.101 | -2.195 |
| Farm size | 0.121 | 0.103 | 1.174 |
| Loan amount | -0.213* | 0.101 | -2.709 |
| Loan terms | 0.613** | 0.204 | 3.007 |
| Interest rate | -0.428** | 0.123 | -3.479 |
| Distance to banks | -3.076* | 1.071 | -2.187 |
| Model Diagnostics | | | |
| LR $Chi^2$ | 29.71 | | |
| Pseudo $R^2$ | 0.670 | | |
| Prob > $Chi^2$ | 0.000 | | |
| Wald $Chi^2$ | 27.42*** | | |
| Observations | 95 | | |

***, **, * denote significance at 1, 5 and 10%.

Source: Author's survey data.

From the results, farmers' repayment abilities were been determined by secondary occupation, attainment of formal education, household size, loan amount received, loan terms, interest rate, and distance to rural banks' premises. Specifically, age and gender of the household head did not show any important implication for determining the loan repayment abilities of farmers. This aligns with the findings of [7, 2]. Secondary occupation was a positive determinant of repayment because farmers can generate secondary sources of income to meet rural bank's payment deadlines. However, this finding is opposite to that of [7] that off-farm income activities negatively influence the loan repayment abilities of farmers. The positive and significant coefficient of educational attainment suggests that it improves farmers' chances of repayment by 4.6% compared to their non-educated counterparts. The current findings agree with that of [31, 3]. Household size with significant and negative coefficient suggests that farmers with larger family sizes are likely to be loan defaulters due to fund diversion to meet household needs. The amount of loan received, and the loan term also known as the payment period are significant determinants of the repayment ability of farmers. The negative coefficient of loan amount suggests that farmers who are earning loans that are not commensurate with their farming needs will incur debt. [36, 25] postulated that larger loans and longer loan terms improve the repayment abilities of borrowers. Interest rate was a negative determinant of farmers' repayment abilities because, at higher interest, farm profits sometimes fall short of investments. Finally, distance to the bank with its negative coefficient indicates that farmers distanced from RCBs are likely not to meet repayment deadlines.

## CONCLUSIONS

This study aimed at identifying the causes of loan default among cocoa farmers who accessed credit from the two major rural and community banks in the Bodi district in Ghana. The probit model, five-point Likert scale, and descriptive statistics were used for data analysis. Results indicated that out of 95 farmers who accessed credit from the two RCBs, 65 defaulted in repayment. The RCBs value the use of collateral as the single most important factor before granting credit to farmers. Rural banks' predicaments of issuing credits to farmers include misappropriation of funds, high default rate, and high illiteracy rate of farmers. The loan use of credit takers which can accurately predict their repayment ability was investigated under three user categories namely (i) farm use, (ii) non-farm use (iii) consumables/ durable goods. Averagely, farmers invested 44.6% of their funds in cocoa cultivating activities- farm use. Non-farm uses of credit absorb a mean of 25.02% of funds and include spending on school fees, trade expansion, and the building of houses. The loan spent on consumption, and durable goods accounted for 30.32% of the amount borrowed. In total, a sum of Gh¢ 850,000 was loaned to farmers, and Gh¢ 389,000 was recovered producing a recovery rate of 45.76% and a delinquency rate of 54.23%. Investigating the causes of delinquency among the 65 defaulters, 24.60% of the causes were attributed to the borrower, 32.04% causes due to the lender, and 43.36% of causes due to nature. RCBs perceived causes of loan default among farmers include misappropriation of funds, unwillingness to pay, the risky nature of cocoa farming, and the high-interest rate charged on loans. From Probit estimation, farmers' repayment abilities were influenced by secondary occupation, formal education, household size, loan amount received, loan terms, interest rate, and distance to the bank. With the above findings, we recommend that RCBs develop a comprehensive loan monitoring system that seeks to reduce cocoa farmers' loan diversion to non-agricultural-related activities.

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# MANAGEMENT OF MYCOTOXINS CONTAMINATION OF FEED INPUTS ON THE AGRI-FOOD CHAIN

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***Abstract***

*Mycotoxins are toxic compounds for animals and humans, naturally produced by different types of fungi. Exposure to mycotoxins through the consumption of contaminated food or feed leads, among others, to gastrointestinal and renal disorders to the point of immune deficiency and cancer. Most mycotoxins are chemically stable and persist in food processing. Given the implementation of the requirements of the European Green Deal, especially those related to organic products, and in the context of climate change, especially regarding temperature and humidity fluctuations, the increase of the presence of mycotoxins in food and feed is highly expected. However, the evaluation of the degree of mycotoxin contamination in different steps on the food chain, with fast and accurate methods, is still an issue for farmers, especially those producing inputs for feed. In the context of a rising organic products market, the frequency and severity of issues related to mycotoxins contaminations are expected to increase. The current work presents the most recent data on mycotoxins occurrence in the world and in Europe and review the mycotoxins monitoring regulations in Europe and Romania. In the same time, the paper analyses the diverse array of methods of analysis developed in recent years and propose a non-exhaustive list of authorized and accredited laboratories in Romania, where players of the agri-food chain can check the quality of the feed inputs and manage the quality of their products. Our analysis shows an increased interest of the Romanian producers on food and feed safety issues, which led to a diversification of services in mycotoxins analysis field in Romania.*

***Key words*****:** *quality management, food safety, mycotoxins, ochratoxin A, cereals*

## INTRODUCTION

Mycotoxins are secondary metabolites produced by different types of fungi, as *Aspergillus*, *Fusarium*, *Penicillium*, *Claviceps*, and *Alternaria* [7], and are toxic to animals and humans [10]. The term "mycotoxins" was introduced in 1961, after more than 100,000 turkeys died from a mysterious disease called "turkey X disease" in Great Britain [28, 33]. Studies showed that the cause of the disease was actually in the feed, which included peanuts contaminated with aflatoxins, secondary metabolites of *Aspergillus flavus* [28, 33]. Mycotoxins enter the food chain because of crop infection before or after harvest and are mainly found in cereals, dried fruits, nuts and fruits and vegetables [10], but also in molluscs, herbs and spices, feed materials [20]. Exposure to mycotoxins through consumption of contaminated food or from animals fed with contaminated feed, especially aflatoxins, ochratoxin A and toxins secreted by the genus *Fusarium*, (deoxynivalenols) leads to gastrointestinal and renal disorders up to immune deficiency and cancer in humans [10]. In animals, high concentrations of mycotoxins may lead to acute symptoms, while low levels have long term impact on animal performance, which include, but are not limited to reduced weight gain, limited feed efficiency, decrease in egg production, low milk production, reproductive failure, etc. [7]. Mycotoxins in feed represent a particular risk, especially for poultry, as their feed is composed of different ingredients, primarily cereals (rice, wheat, barley, oats, rye, maize, sorghum, and millet), by-products of milling [27], that all are highly susceptible for mycotoxin contamination [26]. The mycotoxins mode of action is generally represented by breaking cell membranes, preventing or influencing the synthesis of DNA, RNA and proteins, both in humans and animals [34]. In the context of increasing the organic production, stimulated by the new European Green Deal, and the large fluctuations in the temperature and humidity regime favorized by the climate change (factors favoring the growth of fungi), an increase of mycotoxins incidence in food and feed is anticipated.

Currently, around 300-400 mycotoxins are known, but only 20-30 of them are supervised by the authorities, due to their increased toxicity [10]. According to other sources, a larger number of mycotoxins is proposed, between 20,000 and 300,000 mycotoxins [33]. According to the EC 2016/1319, special attention must be paid to cereals and cereal products used directly in the feed of animals in own households, because the use of uncontrolled feed in the daily ration should not lead to the exposure of animals to a very high level of mycotoxins [18]. It is also worth mentioning that most mycotoxins are chemically stable and survive household food processing [35, 38]. At global level it was created a committee of scientific experts jointly convened by the World Health organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), called Joint FAO/WHO Expert Committee on Food Additives (JECFA), responsible for assessing the health risk caused by natural toxins, including mycotoxins [38]. International standards and codes of practice for limiting exposure to mycotoxins in certain foods are established by the Codex Alimentarius Commission based on JECFA assessments. European Food Safety Authority (EFSA) pays special attention to the monitoring of mycotoxins in animal feed, financing projects focused on this topic [11], since ochratoxin A (OTA) was proven to be a strong nephrotoxic, hepatotoxic, and teratogenic compound [8]. Intake of feed contaminated with OTA affects animal health and productivity and may lead to the presence of OTA in animal products for human consumption. Control strategies for OTA in food products require immediate identification and removal of contaminated commodities from the food chain [8]. However, current analytical protocols may fail to identify contaminated products, especially in animal feed [5, 7]. OTA is produced by several species of *Aspergillus* and *Penicillium* and is a common mycotoxin that can contaminate food, forming during storage of agri-food products. Its most noticeable and notable effect is kidney damage, but the toxin can also have effects on fetal development and the immune system [38]. To minimize the risk of contamination with mycotoxins, it is important to remember that some molds can produce visible infections, but other can penetrate deep into food without being visible. There are general guidelines for storage, to avoid mold growth, such as efficient drying of goods and keeping them dry, proper storage in controlled, low humidity. However, to minimize the health risk caused by mycotoxins, people are advised to regularly inspect stored grains (especially maize, sorghum, wheat, rice), and avoid damage to the grains before and during drying and storage, as damaged grains are more prone to mold invasion and therefore mycotoxin contamination; to purchase grains as fresh as possible; to regularly check the storage conditions and the integrity of the storage spaces, to store for as short periods as possible and to ensure a diverse diet, which also reduces exposure to mycotoxins, but also improves nutrition [37]. Pre-harvest methods, as using resistant varieties, biological and/or chemical plant protection products and field and harvest management and post-harvest methods as drying, maintaining good storage conditions and chemical protection are also good ways of limiting mycotoxins production [7].

Still, all these measures do not grant themselves that food and feed is safe and mycotoxins free. Despite the efforts and good agricultural practices, it is estimated that today 25% of the world's grain production is contaminated with mycotoxins [35]. Such high pressure on the food safety side requires easy access to fast and sensitive analysis methods with low detection limit values.

As methods of reducing mycotoxins effects, various ways have been tested, including sorbent materials [7], addition of enzymes [27], addition of detoxifying microorganisms [33], etc., both in vitro and in vivo. Among the trials, activated chydrated sodium calcium aluminosilicate, cholestyramine esterified glucomannan, diatomaceous clays, bentonite are the binding agents used in animal feed to prevent the adverse effects of mycotoxins [7, 28]. In addition, biological control of the mycotoxin-producing fungi has been developed, based on antagonistic microorganisms [33]. Still, these treatments imply additional costs and should be correlated with the mycotoxins content.

The present paper reviews the most recent data on mycotoxins occurrence in the world and in Europe and review the mycotoxins monitoring regulations in Europe and Romania. At the same time, the mycotoxins methods of analysis are presented, including the laboratories in Romania that perform these analyses.

## MATERIALS AND METHODS

To reach the paper objective, a comprehensive review of the available online and of offline bibliographical references (Reports, Statistics, research papers, books, textbooks etc.), using the following international databases: Web of Science - Core Collection, Scopus (Elsevier), Science Direct Freedom Collection (Elsevier), Oxford Journals, CAB Abstracts, Google Scholar, simple Google research. The key words used for databases research were "mycotoxin" "mycotoxin definition", "mycotoxins impact, food", "mycotoxins impact, feed", "sources of mycotoxin contamination", "mycotoxins monitoring", "mycotoxin analysis". The search aimed at emphasizing the main aspects related to the subject at the global level, and especially in Europe and Romania. The legal framework regarding mycotoxins management was provided by Food and Agriculture Organization of the United Nations (FAO), Europe Food Safety Authority (ESFA), European Commission regulations, recommendations, laboratory, World Health Organization, National Sanitary Veterinary and Food Safety Authority Bucharest, Romania and its laboratories operating under the Institute of Hygiene and Veterinary Public Health (IISPV). The content of this article reflects the authors' opinions based on their original approach of the topic, regarding the logical structure of the researched problems, the depth of the detailed information, and the conclusions drawn at the end of the study.

The assessment of the degree of contamination with mycotoxins of feed inputs on the agri-food chain was done within a research project destined to improve quality management of agri-food products.

## RESULTS AND DISCUSSIONS

### Occurrence of mycotoxins contamination of feed inputs on the agri-food chain in the world

As reported by EW Nutrition, one of the biggest companies in mycotoxins analysis, with global coverage, on out of more than 4,000 analyses (over 1,000 samples covering grain and by-products commonly used in animal feed worldwide), 95% of the samples were contaminated with at least one mycotoxin [21].

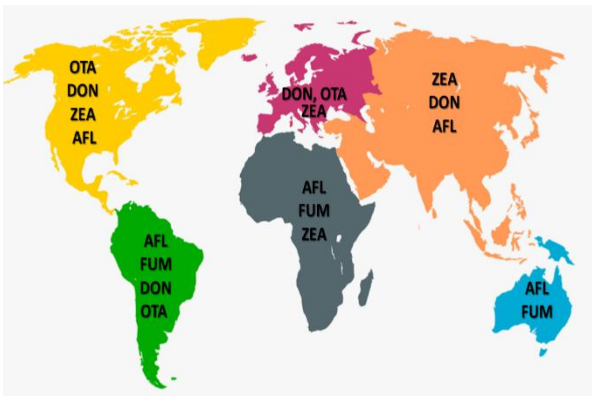


Fig. 1. Distribution of main mycotoxins by continent
Source: [35].

As a common finding of their assessment, most positive samples usually contained three or more mycotoxins, multiple contamination being the most usual [21].

The prevalence of mycotoxins varies by continent; in Europe, deoxynivalenol, ochratoxin A and zearalenone are the most common, while aflatoxins and fumonisins are most common in Australia (Figure 1).

**Occurrence of mycotoxins contamination of feed inputs on the agri-food chain in Europe**

With a solid set of legal acts implemented, EU strives to ensure that food is safe for its consumers, through one of the highest food safety standards in the world.

In 1979 an alert system was created to notify countries as fast as possible about food safety concerns.

Today, the Rapid Alert System for Food and Feed (RASFF) facilitate vital information exchanged in real time, making possible products recalling from the market before they could harm consumers [20].

According to the ACN Annual report 2021, mycotoxins were found in 450 food samples, in 2021, a number which is with 6% higher than in 2020 but with 23% lower than in 2019 [13]. The majority of positive samples – 399, were aflatoxins, of which 273 cases were reported in nuts [13]. As recurrent notifications, dried figs from Turkey where in 57 of cases.

The mycotoxin most frequently found in food was aflatoxin B1, but also ochratoxin A, with 47 positive samples, of which the majority were spices and dried figs [13]. For the current year, there were 414 alerts already issued including the word `toxin`, of the total 1,288 listed.

Out of the total alerts for 2022, 344 alerts where for aflatoxin, of the total of 1074 alerts for aflatoxin, 49 alerts were for ochratoxin A, of the total of 136 alerts, four alerts of lipophilic toxins, out of the total 11 listed, two alerts for azaspiracid toxins, two alerts for mycotoxins, in general, out of the five listed, one staphylococcal toxin out of the two alerts listed, one zearalenone alert out of the two listed, three alerts for fumonisins of the 10 alerts in total, and three patulin alerts out of the total eight listed [13].

As conclusion, in RASSF, mycotoxins represented in 2021 the third most notified hazard category, and three-quarters of the notifications were border rejections [13].

**Mycotoxins monitoring and analysis in Europe**

At EU level, the body coordinating the mycotoxin topic is the Directorate-General for Health and Food Safety [9].

The authority making the recommendations is the European Food Safety Authority (EFSA) [12]. The EU Reference laboratory (EURL) for Mycotoxins and Plant Toxins is the Wageningen Food Safety Research Institute (WFSR), specialized in (forensic) measurements, top level research and development of methods to detect substances in food and feed, for a safe and authentic food [37].

The legislation and regulatory acts in place guiding the mycotoxins' related activities are:

- Commission Regulation (EC) No 401/2006 of 23 February 2006 laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs [14],
- Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs [15],
- Commission Recommendation of 15 March 2012 on the monitoring of the presence of ergot alkaloids in feed and food [17],
- Commission Recommendation of 17 August 2006, on the presence of deoxynivalenol, zearalenone, ochratoxin A, T-2 and HT-2 and fumonisins in products intended for animal feeding [16].

Therefore, the Commission for Food Safety Recommendations includes the following mycotoxins to be monitored:

-Aflatoxins
-Fusarium toxins
-Deoxynivalenol
-Fumonisins
-Nivalenol
-T-2 and HT-2 toxin
-Zearalenone
-Ochratoxin A
-Patulin (Figure 2)

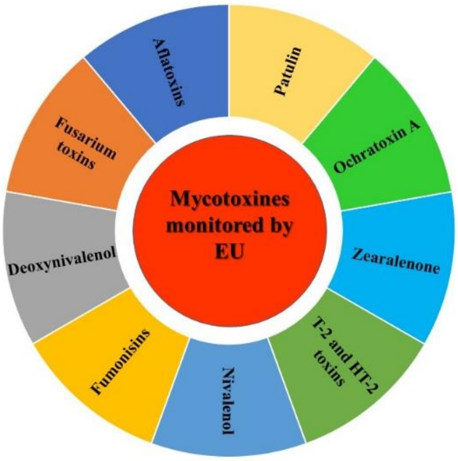


Fig. 2. The mycotoxins that should be monitored as recommended by the EU Commission for Food Safety
Source: Own design based on [10].

In addition, following the EFSA opinions, the Standing Commission for Food safety also recommended the following mycotoxins to be monitored:
-Sterigmatocystin,
-Ergot alkaloids,
-Phomposins,
-Alternaria toxins
-Citrinin [19].

The Standing Committee on plants, animals, food and feed, the section of Toxicological Safety of the Food chain, held in Brussels several meetings in the period 2012-2014, and issued a ”*Compilation of agreed monitoring recommendations as regards the presence of mycotoxins and plant toxins in food*”, a document that includes valuable data on the methods, the limits of quantification and the foods /feeds to be targeted for monitoring the presence of tropane alkaloids, sterigmatocystin, deoxynivalenol, ergot alkaloids, phomopsins, citrinin, pyrrolizidine alkaloids, and Alternaria toxins [19, 31].

**Mycotoxins monitoring and analysis in Romania**

In Romania, the responsible authority for mycotoxins monitoring and analysis is the National Sanitary Veterinary and Food Safety Authority, Bucharest (ANSVSA), by the laboratories operating under the Institute of Hygiene and Veterinary Public Health (IISPV).

These laboratories, functioning as National Reference Laboratories (NRL), are:
- NRL for Mycotoxins and Plant Toxins in Food Products of Animal Origin and Animal Feed
- NRL for Mycotoxins in Food Products of Non-Animal Origin.

As regulatory acts, beside the EC regulations and recommendations, in Romania the following laws are in place:
- Order no. 63 of October 10, 2012 for the approval of the Veterinary Sanitary Norm that establishes the minimum standards regarding the protection of birds on the farm and during transport [3],
- Decision no. 1156 of December 23, 2013 for the approval of the sanitary-veterinary actions contained in the Program of actions for surveillance, prevention, control and eradication of animal diseases, of those transmissible from animals to humans, animal protection and environmental protection, identification and registration of cattle, pigs, sheep, goats and equids, of the actions provided for in the Food Safety Supervision and Control Program, as well as the related tariffs [4].

A special care related to animal feed is given by the law to the poultry feed, the maximum level of mycotoxins being the following:
a) deoxynivalenol: 8 mg/kg for cereals and cereal products, 12 mg/kg for corn products and 5 mg/kg for combined feed;
b) zearalenone: 2 mg/kg for cereals and cereal products and 3 mg/kg for corn products;
c) ochratoxin A: 0.25 mg/kg for cereals and cereal products and 0.1 mg/kg for combined feed;
d) fumonisin: 60 mg/kg for corn and corn products and 20 mg/kg for combined feed.

These values are the same for the breeding hens, chickens intended for meat production and turkeys intended for meat production [3].

In Romania, besides the central and local laboratories of the ANSVSA, there are also private laboratories that perform mycotoxins analysis, all of them being authorized both by the ANSVSA and accredited by the Romanian Accreditation Association (RENAR).

The entities listed in Table 1 are the first that appears on a simple Google search, using the key words “mycotoxin analysis”.

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Table 1. The Romanian authorized laboratories to perform mycotoxins analysis

| Laboratory name | Region / City | Matrix | Mycotoxin |
|---|---|---|---|
| **IBA București** | Bucharest | Very diverse | DON, AFL, ZEA, OTA, AFLM1 |
| **ICA Research & Development** | Bucharest | wheat, corn, spices, coffee, animal feed | DON, OTA, PA, T-2 / HT-2ZEA |
| **APIS Laboratories** | Moldova / Iași | milk, milk powder, animal feed, grains, grain products, corn-based foods and nuts | DON, ZEA, OTA, AFL, FUM |
| **IQLAB Service SRL** | Bucharest | Food and feed | AFLA, OTA, ZEA, DON |
| **Eurolab laboratory services** | International | Food and feed | MYC, AFL-M1, AFL-B1, DON, FUM, DAS, HT-2, OTA, PA, OTB, CTN, T-2, ZEA |
| **SGS Romania S.A.** | International | Not specified | Available on request |
| **Synevovet** | International | Diverse matrixes | AFLA, AFL-B1, AFL-M1, OTA, DON, ZEA, FUM, T-2 |
| **Primoris Bulgaria** | Plovdiv, Bulgaria | animal feed, cereals and cereal products, coffee, dried fruits and nuts, milk, baby food, apple | AFL, DON, AFL-M1, FUM, T2, OTA, ZEA, ERG, PA, TA |
| **ALS Laboratories** | Ploiesti, Deva, Iasi | cereals, dried fruits, nuts, spices, cocoa | DON, AFL-M1, OTA, ZEA, PA, T-2 |
| **LABROM** | Bacau, Alba Iulia | animal feed | AFL, OTA, DON |

| | |
|---|---|
| **Aflatoxins (AFL)** | **HT-2 toxin (HT-2)** |
| **Aflatoxin B1 (AFL-B1)** | Mycotoxins (MYC) |
| **Aflatoxin M1 (AFL-M1)** | Ochratoxina A (OTA) |
| **Citrin (CTN)** | Ochratoxina B (OTB) |
| **Ergot alkaloids (ERG)** | Patulin (PA) |
| **Fumonizin (FUM)** | Tropane alkaloids (TA) |
| **Deoxynivalenol (DON)** | T-2 toxin (T-2) |
| **Diacetoxyscirpenol (DAS)** | Zearalenon (ZEA) |

Source: Own conception.

## Mycotoxins analysis methods

Today, a high number of methods of analysis for mycotoxins are available, but researchers in food safety are continuously developing new methods, to obtain a faster and more reliable result. Among the developed methods, we name the thin layer chromatography (TLC) [30], gas chromatography - mass spectrometry (GC-MS) [6], liquid chromatography - tandem mass spectrometry (LC-MS/MS) [2; 24; 29], immunologic method - ELISA (Enzyme linked immunosorbent assay [22, 23], gold nanoparticle-based immunochromatographic assay. These quantitative methods, are based on different extraction and clean-up techniques, such as: liquid–liquid extraction (LLE), immunoaffinity columns (IAC), supercritical fluid extraction (SFE), solid phase extraction (SPE) [36], solid phase microextraction (SPME) [39], cation exchange resin [32], liquid-liquid microextraction in porous hollow fibers, and solid bar microextraction (SBME) - which using uses only a few milligrams of a sorbent wrapped in a hollow fiber micro-tube [1]. One of the most used methods for ochratoxin A analysis in feed inputs is the HPLC-FLR technique after purification on immuno-affinity columns due to its high sensitivity. Fluorimetric detector for HPLC remains the classical and stable method with a wide application area in mycotoxins analysis, where the influence of matrix is negligible.

In 2018 an LC–MS/MS method for the simultaneous determination of citrinin and ochratoxin A in a variety of feeds and foods was developed and validated, which shows the scientific community's concern for this challenge [25]. This method is also rather expensive, usually time-consuming and requiring deuterated internal standard, for these reasons, LC-MS/MS is more often used for the elucidation of OTA metabolites and for structural confirmation.

## CONCLUSIONS

Mycotoxins are an increasing threat for food security, despite the efforts done to improve the agricultural practices and the post-harvesting practices. In the last years, special attention was given to the mycotoxin issues, many official recommendation and regulations being issued by the competent authorities, in the world, Europe and Romania. Despite the measures taken and awareness campaigns organized by different stakeholders, mycotoxins are still an issue of concern and the research on new methods for more sensitive and reliable results is ongoing. Diverse methods of analysis have been recently developed and many new authorized and accredited laboratories in Romania allow not to the players of the agri-food chain to check the quality of the feed inputs and manage the quality of their products. There is an increased interest of the Romanian producers on food and feed safety issues, which led to this diversification of analysis in Romania, including for mycotoxins that are not included in the EU or National regulations as mandatory.

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# OPPORTUNITIES IN ORGANIC BREEDING OF CAPON POULTRY AND SUSTAINABLE FARM MANAGEMENT

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***Abstract***

*Against the background of the scandals regarding the contamination of food with dioxin and nitrophenol, the Bovine spongiform encephalopathy (BSE - "mad cow" disease), the avian and swine flu, the infection of some vegetables with the enterohemorrhagic strain of the bacterium Esterichia coli (EHEC), as well as the fears regarding the use of genetically modified organisms, the request of agricultural products and ecological food increased a lot at the beginning of this millennium. An opportunity for the transition from subsistence agriculture to an agriculture based on economic principles is represented by systems of exploiting poultry on the ground, with free access to outdoor paddocks, as well as ecological growth. In this context, the present paper tries to bring to the fore some opportunities in the organic breeding of some poultry with a special taste, such as capons. The main objectives followed were: some historical landmarks regarding the growth of capons; the review of the practical elements of capon growing and some case studies that show the opportunity of capon growing in Romania for a successful business. The used methods included searching of the various databases with the latest publications in the field and identification of some relevant results. The breeding of capons represents an opportunity for Romanian farmers who want a profitable business, especially since currently, in Romania, the number of such micro-farms is very limited.*

***Key words*****:** *capon, Breese, flavourful, opportunities, organic*

## INTRODUCTION

The theoretical foundations of organic farming were between the years 1920 - 1960, immediately after the beginning of the process of industrialization of agriculture and the start of the "green revolution", by Rudolf Steiner in Germany, the founder of the concept of "agriculture biodynamic", Sir Albert Howard in England, on whose ideas the school of "organic agriculture" was founded, H. Műler in Switzerland, author of the concept of "organic-biological" agriculture and C. Lemaire and J. Boucher in France, the founders of the "biological agriculture" school.

In order to switch to organic production, a conversion plan is drawn up in advance, which can be carried out at the level of the farm or a well-defined plot of land and is evaluated every year, on the occasion of the control. All components of the conversion plan are established by mutual agreement with the inspection and certification body, in accordance with the legislation in force.

The conversion process is carried out over a sufficient period of time, during which an "adaptation" occurs, both of the ecosystem and of the farmer. Following the conversion process, the land, crops, harvest and animals must acquire the qualities specific to organic production [3, 14].

For animals, the mandatory conversion period is as follows:

• 12 months in the case of equidae and cattle, including the *Bubalus* and *Bison* species for meat production and in any case at least three quarters of their lifetime;

• 6 months in the case of small ruminants and in the case of pigs and animals for milk production;

• 10 weeks in the case of poultry for meat production, brought to the holding before reaching the age of three days;

• 6 weeks in the case of poultry for egg production [14].

In Europe, the relationship of consumers with organic production is exceptional [9]; from the point of view of organic area (% share of total utilised agricultural area), countries like

Austria, Estonia, Sweden, Italy, Czechia and Latvia is on the first places (Figure 1).

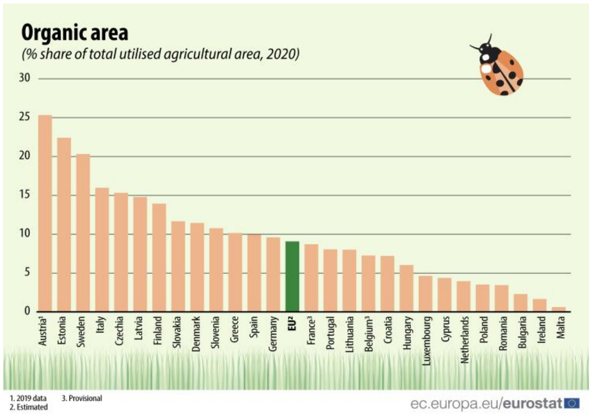


Fig. 1. Situation of organic farming in the European Union (2020)
Source: [9].

In an online statistical study conducted globally in 2016 (Nielsen Company, USA), consumers motivate their tendency to consume organic food as follows: these products are healthier (76% of respondents); want to avoid pesticides and other toxins (53%); organic foods have more nutrients (51%); it is healthier for the environment (49%); food is tastier (45%); etc. (Figure 2).

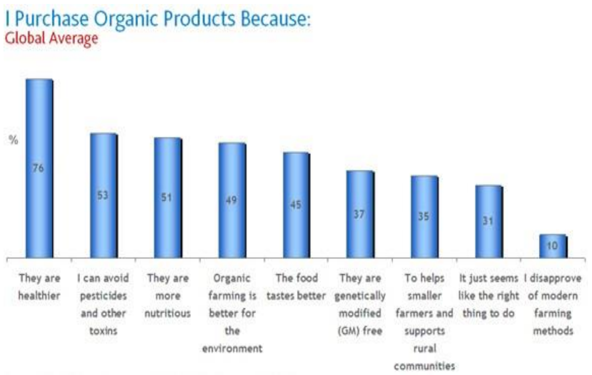


Fig. 2. The main reasons listed by consumers for the trend of choosing organic food
Source: [13].

Health-related problems seem to assume greater importance than concerns regarding the protection of the environment and, in particular, are related to the provision of healthy nutrition, motivated by ecological and hygienic-sanitary arguments, imposed by the radical change in consumer demand and the on-going concerns more insistent for food biosecurity.

Capon is a male chicken that is caponized (castrated) after reaching the age of 9 weeks. Proper care and feeding produce the appearance of thin layers of fat inside the muscle tissue, and this fact leads to the tenderness of the meat and a special taste [4, 15]. Thus, the capon meat is more delicate and flavourful than that of a hen or rooster, which is due to the way they are fed but also to hormonal differences during the development of the capon [12, 16], as well as the fact that these poultry are not as active like the ordinary roosters. Because of the loss of sex hormones, the normally aggressive rooster becomes docile and mellow capon.
According to the writings of Pliny the Elder in L'Histoire Naturelle, the Romans are credited with the invention of the valve, as early as 162 BC when Senator Gaius Fannius Strabo passed a law for limiting the consumption of chicken meat. The objective was to save the grain reserved for plebeian’s food (the bottom layer of Roman society). The restriction mandated the consumption of a very small number of chickens at banquets, birds that should not have been fattened for this purpose. The senator suggested castrating the young roosters and feeding them dairy products, later finding that the roosters doubled in weight and size [7].
The story of the Bresse capons, the most famous breed, originally from France, began in 1591 in Bourg-en-Bresse, based on the local breeds Black Louhans, Gray Bourg-en-Bresse, White Beny. King Henry IV is said to have been seduced by the aroma of poultry given as a gift by the inhabitants of Breese [7].
In 1825, Brillat Savarin in his book "Physiology of Taste" brings the Bresse breed to the fore and calls it "Queen of poultry, from the court of kings". Later, Bresse poultry became known in all European capitals.

## MATERIALS AND METHODS

In this short review, some main objectives were followed, namely: the positive impact of ecological agricultural practices on the environment and consumers health; some of the main reasons for choosing healthy foods that ecological consumers support; some historical landmarks regarding the growth of capons; the review of the practical elements of capon growing and some case studies that show the opportunity of capon growing in Romania for a successful business.

The used methods included searching of the various databases with the latest publications in the field and identification of some relevant results. The main databases were Web of Science and Google Scholar as well as EUROSTAT and MADR statistics. The case studies from Romania were obtained from some online magazines like Ferma, Agrointel and Adevarul.

## RESULTS AND DISCUSSIONS

During the transition period from the communist era to the market economy, a number of poultry farms in Romania were closed down. Currently, most poultry farms are privately owned. In the pre-communist period, there were famous capons breeders and there was an important market; during the communist regime, however, it disappeared altogether, at the present time many consumers do not know anything about capons and have never tasted their meat.

The capon can be slaughtered only after exceeding the age of 150 days and a weight of at least 3 kg. It is generally ready for sale around Christmas.

On August 1, 1957, the French National Assembly voted to grant the title of Designation of Controlled Origin (Appellation d'origine contrôlée/AOC) to the Bresse breed of capons, and in 1976 to the Dinde de Bresse breed, which became AOP (Appellation of Origin protected). There is even a grouping of Breese capons breeders, established on December 15, 1962, shortly after AOC decree, which defines the production conditions of the Bresse capons. This grouping brings together the most responsible breeders.

In France, Spain and the United States, the capon is considered a festive chiken, and in Romania, at the great noble houses of the past there was a real cult for capon meat, with tasty recipes. Today, some luxury restaurants from our country have begun to include capon meat in their holiday menus.

The French, the most famous capon breeders in the world, recommend the following breeds: La Bresse (predominant) but also the La Fleche, Faverolles, Label rouge breeds. According to the experts, the best capons are those from the Bresse breed, which have finer muscle fiber and finely divided fat deposits [7].

AOC requirements for the Bresse flap breed:
- Growing in freedom on grassy areas;
- Feeding with cereals, milk and dairy products, worms and molluscs;
- In the final fattening stage, feeding with honey for 4 weeks;
- Minimum weight: 3 kg;
- Marketing: 1 to 31 December;
- Commercial presentation: usually with the feathers on the head preserved, for the guarantee of the brand (Photo 1).


Photo 1. Two different commercial presentation of Breese capon
Source: [2].

Being raised in an organic system, Breese capons gain weight a little harder. If broilers reach 2.5-3.5 kg in less than 42 days, La Bresse breed capon reach 3.5 kg in 150 days with an intelligent feed based exclusively on grain combinations, but the difference in volume between them and other types of chicken carcasses is noticeable (Photo 2).

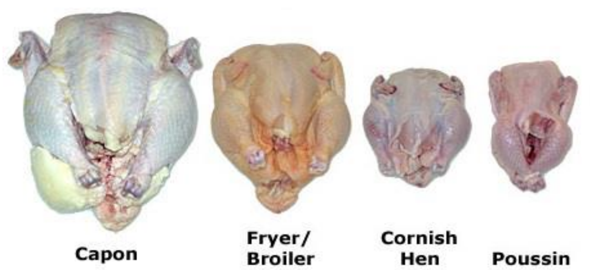


Photo 2. Types of chicken. Capon has more white meat and higher fat content than other chickens.
Source: [15].

The rearing technology consists in growing exclusively in freedom, on pasture, in grassy spaces for 5 - 6 months. The feeding is done with cereals and protein crops of vegetable origin, as a supplement to grazing. In the Bresse breed, finishing is done at the age of 7-8 months, with corn and wheat soaked in milk.

Capons can be raised properly by feeding them only organic feed. From the time they are small, chickens need food that provides them with a minimum of 20% protein and about 3,000 calories daily. During the first 2 weeks they need a constant temperature of 28$^0$C, as well as constant access to water and very finely ground grain, so that digestion is easy.

Capons must have a combined feed that contains all the elements they need for increased and healthy growth performance. The breeder must always pay attention and care to this poultry, because the breeding process is a complex one.

Their feed must contain carbohydrates (cereals - corn, wheat), proteins (soybean and sunflower groats, peas, bran), minerals (salt, calcium) and vitamins (grassy areas must also contain alfalfa and clover), all of which are necessary for the formation of bones, muscles and fat. Practically, 1/3 of the capon's food must be taken from the grassy spaces. In freedom, capons tirelessly eat worms, molluscs, grass and seeds throughout the day [11].

Water is very important in the nutrition of capons. In general, they consume about 2 times the amount of food; on hot days, they will drink up to 5 times more water. It is very important that the water is always fresh, and where possible it is recommended to use spring or well water [11].

In order to comply with the conditions regarding the system of capons growing on the ground, with free access to the paddock, from a functional point of view, a farm must have the following areas [6]:

- Veterinary sanitary protection area;
- Access driveway to the farm;
- Outdoor access paddock. The area required for capons access is delimited by a fence;
- Paddock access gates.

The perimeter of the farm must be protected with a mesh fence. Access to the perimeter of the production farm by foreigners is strictly prohibited. Employed personnel enter the production space only in compliance with biosecurity protocols [6].

The "caviar" nickname of the capon is due to the price of the meat, which can reach from 10-12 Euro/kg to 50-80 euro in the case of Bresse breed capon. The age of this breed and the fact that it is not genetically modified have determined the extraordinary resistance of Bresse capon. Basically, this breed does not show any sensitivity and it is recommended to be raised in an extensive system with natural food. They also lend themselves very well to growing in freedom - free-range, being birds with a lively temperament and great mobility. That's why Breese breed capon can also be recommended in Romania, where, 50 years ago, they were the main delicacy at all the noble courts.

Romania could become a good producer for this ecological poultry, exceptionally tasty and very well paid. The capon casing is eviscerated, and the feathers on the head and sometimes the tail are left intact so as not to mislead customers. In general, the weight of the carcass is around 3.5-5.5 kg, depending on the breed and the way of exploitation.

The opportunity for the capons breeding in Romania is also given by the extremely small number of breeders; thus, there are only a few micro-farms, e.g. in Lăpusel (Maramureș), Câmpulung (Argeș) and Baia Mare.

The system of growth and exploitation free range growth system of capons complies with the community rules regulated by Regulation (EC) No. 543 of June 16, 2008 establishing the rules for the application of Regulation (EC) no. 1234/2007 of the Council regarding the standards of commercialization of poultry meat, art 11 and annex V, where it is specified "Free-range" [6].

This term can be used only if:

- The capon’s density is no more than 7.5 per m$^2$, provided that they weigh no more than 27.5 kg live weight per m$^2$;
- They had continuous access during the day to external paths covered mainly by

vegetation and representing at least 2 $m^2$ per capon;
- The food formula used during the fattening period contains at least 70% cereals;
- The shelter is equipped with exit hatches with a combined length of at least 4 m per 100 $m^2$ of shelter surface [6].

Because they are genetically resistant breeds, antibiotics are excluded from the meat of Breese capons. Farmers can use, if necessary, natural antibiotics (thyme oil or oregano oil), administered in water. However, there are certain obstacles in capitalizing, determined on the one hand by reluctance and on the other hand by the fact that the luxury restaurants that capitalize on this meat prefer to work with imports than with Romanian goods. It can be stated that for capon meat it is a growing market, but it all depends on the restaurants. In Romania, they can be produced at lower costs, compared to the costs at which they are grown in other countries [11].

Increasing the capons, however, requires specialists for the caponized procedure, a very delicate operation [8]. The biggest problem faced by a Romanian capon breeder is the high mortality following caponization, as there are very few specialists who can successfully perform this operation. Also, one of the major disadvantages is that the mortality rate after caponization is very high: almost half of the capons die after the operation, a fact that can discourage any investor. However, after three series of 100 heads, the business starts to work, according to the statements of a capon's breeder from Lăpusel (Maramureș), who in 2013 re-established the first farm of this kind in Romania. The farmer sells the carcasses of capons (of various breeds) in luxury restaurants, at advantageous prices, which ensure an excellent profit [5].

In 2016, a Bucharest resident decided to start a business with capons from the Breese breed in Câmpulung-Arges (Photo 3).

The farmer invested in the Bresse breed starting from a queen flock of 18 purebred hens, which he obtained from eggs purchased through a distributor from Germany and France. In 2017, it managed to reach an effective number of over 1,000 specimens [11].

Photo 3. Breese capons from Câmpulung (Argeș) microfarm
Source: [11].

The high fat accumulation (Photo 4) is extremely important for consumers seeking better-tasting meat [1, 10].

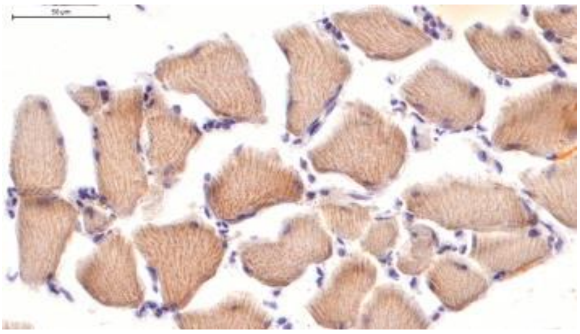

Photo 4. A muscle sample from a 16-wk-old capon and the adipose tissue accumulation
Source: [10].

This type of business can be revitalized today, because the clam meat is a real gastronomic treat.

The market is a niche one; e.g. it is estimated that around one million capons are produced annually in USA, compared to approx. 8 billion chicken heads for meat every year. Currently, commercial production of capons in USA is limited to a single producer, Wapsie Produce Company, in Iowa State.

In Europe, France is the largest producer, with over 2 million capons/year.

As the main French region for the production of exceptional poultry, its famous capon brings a bit of Burgundy to many French Christmas tables.

## CONCLUSIONS

The consumer public is alert in terms of product quality, when it comes to meat and other foods.

Capons are a unique type of meat poultry for a specialized market. They grow much more slowly than normal males and accumulate more fat, their meat becoming tenderer and much tastier.

La Bresse breed is among the most famous in the world. It has a meat with a special texture and special taste, close to pheasant, which makes it highly sought after by chefs at luxury restaurants. The "caviar" nickname of the capon is due to the price and special flavour of the meat.

The breeding of capons represents an opportunity for Romanian farmers who want a profitable business. These opportunity is also given by the extremely small number of breeders and micro-farms.

The best breeds for organic capon breeding are those with slow growth. From this point of view, the Bresse breed is recommended, as it is the only one in the world with controlled designation of origin, just like noble wines.

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# HISTORICAL REVIEW OF AGRICULTURAL COOPERATION: WORLD TRENDS AND UKRAINIAN REALITIES

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***Abstract***

*The article is aimed at studying the state of agricultural cooperation in Ukraine in a historical retrospective. It is shown that before the October Revolution of 1917, cooperation in the country successfully developed, was profitable and convenient for participants in cooperatives. The methods of pseudo-cooperation, which were practiced in the USSR and received the collective name "collectivization", are analyzed. It has been proved that collectivization and cooperation differ in essence; this is confirmed by the unprofitability of collective farms and the fact that they consistently received subsidies from the state. The main problems of agricultural cooperation in Ukraine from 1991 to the present time are revealed. The regulatory and legal support of this sphere and its change are analyzed, taking into account the international documents signed by Ukraine, as well as Ukraine's obtaining the status of a candidate country for joining the European Union. It is shown that at the present stage, under martial law, the functioning and development of cooperation is difficult, but there is reason to expect an improvement in the situation after the cessation of hostilities on the territory of Ukraine. The statistics used in this study are taken from the official website of the State Department of Statistics of Ukraine; records of agricultural cooperatives have been kept since 2004.*

***Key words*****:** *agriculture, production cooperative, service cooperative, cooperation, Ukraine*

## INTRODUCTION

Today, the market economy in Ukraine is at the stage of development, the constant search for new methods of labor organization continues. It is important to restore successful forms of economic activity that were already functioning before the country's accession to the USSR, such as agricultural cooperation. This cooperation has proven itself all over the world from the best side; it causes a strong growth in the welfare of the rural population and the development of rural areas. Agricultural cooperation has a direct or indirect influence on all aspects of village life. Thanks to this type of cooperation, declining territorial communities have a chance to survive. Functioning on the territory of a successful enterprise means: preserving and creating new jobs; improving the quality of life; stopping depopulation and much more. The presence of the factor of competition between individual agricultural producers should also be taken into account, world experience shows that cooperatives have much more opportunities to establish cooperation with consumers, intermediaries, processing and trading enterprises than individual farmers. The same applies to the joint ownership of expensive equipment and machinery, which is a great difficulty for individual farms. Realizing the importance of agricultural cooperatives, the state takes certain steps to support them and encourage their creation, develops programs for the development and support of agricultural service cooperatives, strategies for the development of regions, which take into account the importance of cooperation for the harmonious development of territories; the approved State target program for the development of Ukrainian villages and much more. However, there are still many difficult moments and problems in the field of agricultural cooperation, caused by external and internal circumstances, and therefore scientific research in this direction remains relevant. For a deeper understanding of the conditions in which the cooperative movement was born, it is advisable to turn to the newspaper "The Co-operator", which was the first to promote the ideas of cooperation. Later, a collection containing the most important issues of the newspaper for the period 1828-1830 was published. The motto of the cooperative was repeated on the front page of each issue of the newspaper: "Knowledge and union are power. Power, directed by knowledge is happiness. Happiness is the end of creation" [35].

Current information on the state of cooperation in the world is available on specialized Internet sites, among them: International Co-operative Alliance (free access online library) [15]; Coop News [6], Co-operatives UK [7] and other. V. Honcharenko investigated the peculiarities of the historical models of the Ukrainian credit cooperative [11]. Yu. Tymchenko revealed the peculiarities of consumer cooperation in Ukraine during the period of the New Economic Policy (1921-1928) [39]. N. Kuevda and A. Revutska compared the past and present state of agricultural cooperation and formed forecasts for the future [18]. I. Hlotova singled out the most successful practices of the cooperative movement [10]. The works of M. Hrytsenko [13], V. Bondarchuk, J. Alkoley, L. Moldovan and others [3] analyze the high productivity of the world's agricultural service cooperatives. S. Labaziuk proved the need for urgent reorganization of agricultural cooperation in Ukraine [19]. Encyclopedic editions were used to clarify individual terms and wordings in the paper [9]. The legal basis for the functioning of agricultural cooperatives is the legislative framework of Ukraine and international documents to which Ukraine is a party [34], [21], [2], [8], [24], [22]. A. Panteleimonenko [26], [27] and V. Honcharenko [12] investigated the imperfections of the regulatory and legal support for the work of cooperatives.

In this context, it is advisable to conduct a separate study of the possibilities for the development of agricultural cooperation in Ukraine, taking into account past experience and current global trends.

## MATERIALS AND METHODS

The paper mainly explores the possibilities of developing agricultural cooperation in Ukraine. For a deeper insight into this process, the historical origins of cooperation in the world are considered.

Ukrainian cooperation in the pre-Soviet period developed quite successfully and more and more farms were involved in it. As a result of the 1917 revolution, the established system was disrupted and cooperation actually ceased to exist. Food problems in the country forced the Soviet government to develop the so-called "New Economic Policy", which, among other things, provided for the restoration of the cooperative movement. However, the NEP did not last long and was replaced by a policy of collectivization, which completely contradicted the essence of cooperation. The restoration of agricultural cooperation in Ukraine began only after 1992 and continues to this day.

The main analyzed indicators are: official statistical information on the number of agricultural cooperatives in Ukraine since 2004; normative and legal support of cooperation, including the main changes made to the legislation; problems of cooperation that arose as a result of martial law in Ukraine and possible ways to solve them at the present stage. Numerous sources were used to write this paper, including: scientific publications of Ukrainian and foreign scientists, statistical information, specialized materials.

The research results are presented in the form of tables and diagrams.

## RESULTS AND DISCUSSIONS

The first documented cooperative in Europe was the association of weavers in Fenwick

(Great Britain) created in the 18th century. In 1844, the consumer cooperative of weavers in the city of Rochdale (England) formulated the fundamental principles of the functioning of enterprises of this type, which were of great importance for the further development of the entire European cooperation [25] and were named "Rochdale principles" (hereinafter – the Principles).

The principles have been officially approved by the International Co-operative Alliance (hereinafter – ICA) and in the latest version (2013) have the following form [14, p. 3]:

- Voluntary and Open Membership
- Democratic Member Control
- Member Economic Participation
- Autonomy and Independence
- Education, Training and Information
- Co-operation among Co-operatives
- Concern for Community

Today, cooperatives are distributed to almost all areas of the European economy, and work regardless of size wherever it is profitable: from very small ones operating in rural areas – to extremely large ones that unite powerful producers.

Global practice shows that cooperatives are much more sustainable than individual farms. They are almost twice as likely to survive the early years of existence when compared to other start-up businesses. More than three quarters of co-op start-ups (76%) are still flourishing after the difficult first five years. Other business forms are far less likely to survive, with only 42% of all new companies making it through to the end of year five [15, p. 4].

Today, there are more than 300,000 cooperatives in Europe, in which more than 140 million people participate. According to international experts, France has the most developed cooperation among all European states. There are more than 21,000 cooperatives with a turnover of 260 billion euros and about 23 million people are employed. The French cooperative movement covers various sectors of the economy. At the request of the French government, a thorough study of the country's 100 most powerful cooperatives was conducted. It turned out that their sales amount to 181 billion euros, and the number of participants is 22 million people (674 thousand service personnel). It is significant that 65 of the top 100 cooperatives in France are agricultural, with more than 300,000 joint partners and 100,000 service workers, about 75% of French farmers are united in cooperatives [38].

In Germany, the largest share is occupied by cooperatives in the agriculture and food industry sector (28.7%) [5, 25].

The relief of Spain is predominantly mountainous and there is little land suitable for agriculture [30]. However, the country successfully produces agricultural products and is among the Top-10 world exporters [28]. This is a great merit of local cooperatives, for example, horticultural products are produced on family farms united in agri-food cooperatives, the total number of such cooperatives in Spain is 3,200 units [4].

The share of agricultural cooperatives in the agricultural market of the EU is 40-50%, and in some states and sectors it reaches 70%. The annual turnover of the 10 largest cooperatives in the EU is more than 93 billion dollars, which is almost equal to the annual GDP of Ukraine [19].

Today, there are more than 700 million cooperatives worldwide. The activities of some of them have long gone beyond the borders of a certain country – they are powerful transnational associations with thousands of employees and billions in earnings. For example, National Agricultural Cooperative Federation or NACF is an umbrella organization for Korean agricultural cooperatives. The 1,155 primary member cooperatives represent over 2.35 million member farmers in Korea. NACF was founded in 1961 and provides supply, processing, marketing, and banking services. Nonghyup operates a number of retail grocery stores. Nonghyup provides about 50% of rural food marketing in South Korea. Nonghyup was ranked fourth among the 300 largest cooperative organizations in the world [20].

In countries such as Sweden, Denmark, Norway, the Netherlands, and Japan, cooperatives cover 100% of agricultural producers. In most of these countries, cooperatives are organized according to the sectoral principle, and the largest group is a group of cooperatives for procurement, processing and sales of products. For example, in Denmark they process 90% of commercial milk, produce the same amount of butter and cheese for export, in Finland the participation of cooperatives in the slaughter of cattle and the production of meat products reaches 80% [13].

The UK's agricultural and farming cooperatives are the second largest proportion of the co-operative sector, in 2014 their number was 621 units. 155,000 farmers (approximately half of the country's farmers) are members or co-owners of these enterprises. Over the period 2010-2014, their annual turnover increased from £4.8 billion to £6.2 billion [1]. At the beginning of 2021, due to the impact of the COVID-19 pandemic, consolidation and reorganization took place and the number of agricultural cooperatives decreased to 432 units, but the turnover increased to 7.9 billion pounds [36, p. 7].

In neighboring Poland, cooperatives are market organizations of farmers who voluntarily organize themselves into horizontally and vertically integrated structures with the aim of jointly selling the products of their members. Experts note that the policy of stimulating cooperative associations in the agricultural sector of the economy introduced in Poland, based on the principles of the common agricultural policy of the EU, has given positive results, primarily in the context of encouraging farmers to increase their competitiveness on international markets. In addition, it made it possible to correct some mistakes made at the initial stage of market reforms [3, p. 16-17].

According to the definition of the Great Soviet Encyclopedia, two types of collective property were used in agriculture: the property of collective farms and other cooperative organizations (consumer, housing) and higher in terms of the degree of socialization of property – inter-cooperative property, owned by several collective farms or cooperative organizations [9, p. 473].

The vast majority of these associations in the USSR and Ukraine were created by force, and their property was property taken from the peasants and transformed from private property into collective property, it concerned tools of labor, livestock, materials and other things, this activity of the state was called "collectivization". Work in collective farms and state farms were mandatory, very low-paid, and payment was mostly in kind. People were forced to put up with this under the threat of eviction to other, unfavorable places for life, for example, to the undeveloped territories of Siberia or imprisonment. In addition, passports began to be issued to residents of rural areas only in 1974. Without a passport, which indicated residence, a person had no right to leave his place of residence, get a job, etc. For violation of these rules, the laws of that time provided for severe punishments. Accordingly, the peasants were actually completely lawless hostages forced to live and work under imposed conditions.

Throughout the Soviet period, despite the rich natural resources, Ukrainian agriculture was subsidized. After the collapse of the USSR (1991), state support for agricultural enterprises ceased, liquidation of collective farms, mechanized enterprises that served them and their transition to other forms of ownership began. Enterprises that produced agricultural machinery and spare parts for it (for example, in the city of Lviv – this is the Silmash plant, the Lviv auto tractor spare parts plant, and others) stopped or began to be repurposed. Mass labor migration of working-age peasants to cities and abroad began, which exacerbated the decline of agriculture.

The majority of collective farms, created by the method of forceful association, well known in history under the name "collectivization", were reorganized in the same violent way into new pseudo-cooperatives, which this time were called "payhospiv" or associations of citizens – land owners and co-owners of property shares ("payiv"). At the same time, the "reformers" confidently ignored the fact that a significant part of the new "owners" turned out to be completely indifferent to the unexpectedly obtained "out of nowhere" property, and were not oriented in the legal subtleties of possible management of this property; and also did not have elementary management, economic or agronomic knowledge for its effective use. As a result, they suddenly became members of "new cooperatives" called CAE (collective agricultural enterprises). In fact, these "owners" were not allowed to manage, and for transferring the right to use their property to skilled agricultural workers (usually from among the former heads of collective farms and state farms), they received a symbolic payment in kind. Subsequently, the place of CAE was gradually taken by agricultural holdings, and discussions about the need to develop agricultural cooperation intensified again in Ukraine.

The problem arose of reviving cooperation in a country where, after more than seventy years, there were practically no people left who would remember what a real agricultural cooperative is. The Ukrainian experience of the end of the 19th and the beginning of the 20th centuries is today mostly mentioned in scientific works and intellectual discussions, and the world practice of cooperation is weakly correlated with the Ukrainian traditions of rural management.

The idea of agricultural cooperation came to Ukraine from Europe under the influence of the development of cooperative lending, which arose in Germany in the form of "village funds" by F. Raifeisen and "people's banks" by H. Schulze-Delich. The creation of rural credit societies of the Raifeisen type on the territory of Ukraine, which was part of the Russian Empire, became possible only in 1895 after the adoption of the law "On Small Credit Institutions", which established the possibility of establishing credit cooperatives not only on a share basis, but also on a non-share basis. In 1895, in the village of Ivankivtsy, Prylutsky District, Poltava Oblast, the first credit society of the Raifeiseniv type was established in the entire Russian Empire [11, p. 36].

At the same time, the agricultural cooperation in the territory of Ukraine began to acquire its significant spread only during the Stolypin reform. Thus, at the beginning of 1915, out of 3,750 agricultural cooperatives created in the Russian Empire, 1,500 operated in Ukraine. At that time, the main types of cooperative organizations were cooperative societies [18, p. 67].

A new wave of activation of the Ukrainian cooperative movement occurred during the period of economic policy liberalization under the conditions of the NEP (New Economic Policy). By the decision of the October (1921) plenum of the Central Committee of the RCP(b), the cooperative received certain benefits and advantages in the organization of trade, which were aimed at preventing the growing activity of private traders, who from the beginning of the introduction of the NEP confidently occupied leading positions in retail trade. In December 1922, the property that had previously been nationalized was returned to the consumer cooperative, and it also received monetary and commodity loans from the state to cover organizational expenses at the expense of Narkomprod in the amount of 10 billion krb. The State Bank of Ukraine has increased the volume of lending to the Central Union ("Tsentrospilka"). A committee on cooperation financing was established under the People's Commissariat of Food. In 1923, Vukoopspilka joined the International Cooperative Alliance and began to create its representative offices in individual countries, establishing ties with foreign cooperators. In the same year, the Ukrainian Economic Council adopted a resolution on export-import activities of the Vukoopspilka. In order to conduct trade operations abroad, it was allowed to have its representative offices at the Committee of Foreign Trade of Ukraine (Komzovshtogi Ukrainy), to sell products that were part of the nomenclature approved by it. Ukrainian cooperatives exported agricultural products, mineral fertilizers, soda, lime, vitriol, oil, acids, leather, down, feathers. Since 1923, cooperators began to export bread, which became the main article of Ukrainian export. In 1924-1925, in order to increase the interest of the peasants in establishing relations with the foreign market through consumer cooperation, customs duties on most agricultural goods were abolished, railway tariffs were reduced, etc [39].

Thanks to the new economic policy, market-type cooperatives began to actively revive. The number of primary cooperative societies increased from 8.1 thousand in 1923 to 26.1

thousand in 1928, cooperative unions – from 68 to 114. At the beginning of 1930, there were 4,000 multifunctional cooperatives, 691 credit societies, 1,191 beet growers' cooperatives, 390 dairy and meat cooperatives, and 102 poultry cooperatives working in Ukraine. At the same time, starting from the end of the 20s, cooperative organizations began to acquire more and more features of state structures. The final decline of the cooperative idea began in 1927 after the decision to collectivize agriculture and forcefully organize collective farms. From the very beginning of their establishment, collective farms were declared as cooperative organizations [18, p. 68]. The heads of collective farms and state farms were often appointed people far from agriculture; the main characteristic was the obedient implementation of all instructions sent from the executive committees of the Communist Party of different levels. Such managers did not understand the specifics and did not know the basics of agriculture, this led to the fact that these associations quickly turned into unprofitable ones.

The only reason that prompts peasants to join cooperatives is their own economic interest and potential benefit, but when market mechanisms work poorly, the cooperative movement declines. This happened during the period of "war communism" in 1919-1921, during the period of existence of collective farms (1927-1991), and the same thing happened in the post-Soviet period. That is, cooperation acts as a peculiar indicator of the development of the market environment and the quality of its institutional support. After all, the voluntary association of peasants into cooperatives with the aim of obtaining additional benefits from their work implies a significant increase in the level of economic coordination of peasant households, improvement of their specialization, increases the requirements for the quality of the social capital of the village, etc. This explains the retardation of the development of cooperation in Ukraine, which during all the post-Soviet years did not become sufficiently widespread (Fig. 1).

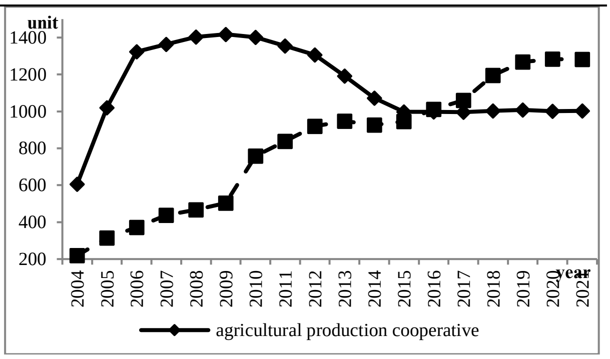


Fig. 1. The number of agricultural cooperatives in Ukraine in 2004-2021.
Source: [31, p.69], [32, p.47], [37].

Figure 1 shows that the dynamics of the development of agricultural cooperatives in Ukraine is unstable, as of the beginning of 2022, the number of service cooperatives significantly exceeds the number of production cooperatives. Some researchers believe that the reason lies in the fact that the rural population equates cooperatives with collective farms and, for the most part, does not see the prospects and potential of this form of management [29, p. 43].

Table 1. Part of agricultural cooperatives in the total number of cooperatives in Ukraine in 2004-2022, units

| | Total number of Cooperatives | Agricultural cooperatives | Agricultural cooperatives, %. |
|---|---|---|---|
| 2004 | 29,616 | 825 | 2.79 |
| 2005 | 30,229 | 1,334 | 4,41 |
| 2006 | 30,790 | 1,696 | 5,51 |
| 2007 | 31,428 | 1,802 | 5,73 |
| 2008 | 33,257 | 1,872 | 5,63 |
| 2009 | 34,324 | 1,921 | 5,60 |
| 2010 | 35,063 | 2,160 | 6,16 |
| 2011 | 29,275 | 2,105 | 7,19 |
| 2012 | 28,675 | 2,139 | 7,46 |
| 2013 | 28,435 | 2,083 | 7,33 |
| 2014 | 28,649 | 2.143 | 7.48 |
| 2015 | 24.868 | 1.908 | 7.67 |
| 2016 | 25.763 | 1.947 | 7.56 |
| 2017 | 26.460 | 2.014 | 7.61 |
| 2018 | 26.975 | 2.069 | 7.67 |
| 2019 | 27.524 | 2.212 | 8.04 |
| 2020 | 28.071 | 2.279 | 8.12 |
| 2021 | 28.596 | 2.195 | 7.68 |
| 2022 | 33.694 | 2.292 | 6.80 |

Source: [31, p.69], [32, p.47], [37].

However, if the reason were so simple, it could be quickly solved by explaining to the villagers the benefits of cooperation. It is obvious that, in addition to certain conservatism inherent in the rural population of all countries, the development of agricultural cooperation is hampered by the imperfection of the legislative framework and institutional support of this sphere. These problems explain such a small percentage of agricultural cooperatives in the total number of cooperatives in Ukraine (Table 1).

Table 1 shows that there are many nominally agricultural cooperatives in Ukraine, but their percentage is very small in the total number of cooperatives.

Service cooperatives, in contrast to production cooperatives, are by their economic essence non-profit organizations that, in the case of securing this status, are subject to Article 133 ("Tax payers") of the Tax Code of Ukraine dated 02.12.2010 No. 2755-VI (edition dated 09.07.2022). Clause 133.4.6 of this article specifies that "agricultural service cooperatives, cooperative associations of agricultural service cooperatives" are non-profit organizations and are not tax payers [34].

Adopted in 2020, the Law of Ukraine "On Agricultural Cooperation" [21] (hereinafter – the Law) simplified the conditions for the functioning of cooperatives and at the same time took into account the need for the gradual adoption of international norms and rules of cooperation, which, among other things, is provided for by the "Association Agreement between Ukraine and the EU" [2]. The law significantly improved the level of legal regulation of agricultural cooperatives, provided an opportunity for members, associate members of a cooperative that operates for profit, to receive dividends, introduced guarantees for associated Correctionmembers, improved the procedure for establishing cooperatives and joining a cooperative, created an opportunity to freely choose the type of activity of a cooperative, made it easier to recognize the cooperative as a non-profit organization [16].

However, in the case of liquidation of a cooperative as a non-profit organization, its assets are transferred by decision of the general meeting to another agricultural cooperative (association of agricultural cooperatives) operating with or without the purpose of making a profit, and in the absence of such a decision, they are credited to the state or local budget [21].

In addition, according to the provisions of the Law, in order to obtain the status "non-profit", a cooperative must meet the following conditions [34]:

1) the cooperative does not produce agricultural products and provides services exclusively to its members;
2) the cooperative does not acquire the right of ownership of agricultural products that were produced, grown, fattened, caught or collected (harvested) by its members – producers of agricultural products. At the same time, the owners of agricultural products harvested, processed, supplied, sold by such a cooperative are its members;
3) the cooperative meets the requirements established by subsection 133.4.1 of clause 133.4 of Article 133 of the Tax Code of Ukraine for non-profit organizations.

The listed conditions mean that the produced products can be sold only in large quantities on the basis of contracts concluded with each member of the cooperative personally. This practice is too complicated and involves a lot of risks, so trading organizations prefer larger deals.

In the event of the creation of an agricultural cooperative in the form of a non-profit organization, its members will not so much reduce their transaction costs as increase them due to the growth of property risks and the actual need to create another non-profit organization that could become the property successor of the cooperative in the event of its termination of its activity.

For non-profit organizations, there are also separate requirements for the submission of tax reports, approved by the order of the State Tax Administration of Ukraine dated 17.06.2016 No. 553 [24], therefore certain difficulties remain in the accounting system in the event that peasant farms join cooperative associations and their transition to the new system reporting. At the same time, it should be recognized that the new form of reporting has advantages over those forms used in the previous period (approved by the relevant orders of the Ministry of Finance of Ukraine dated 31.01.2011 No. 56 [22] and dated 27.01.2014 No. 85 [23]), since the new form the report consists of fewer sections. At the same time, the fact remains that the introduction of changes three times within a short period has created tangible difficulties for agricultural cooperatives and introduced confusion into their work.

In Europe, cooperation acts as a kind of economic ideology, which represents the struggle of small and medium-sized businesses against monopolies, which are so characteristic of the economy of Ukraine. Unfortunately, Ukrainian society lacks a deep awareness of solving its own problems through cooperation [33]. In a number of European countries, cooperation is not divided into types, as it happens in Ukraine, there are simply cooperatives that help farmers in conducting their business.

One of the indicators of progress in the field of regulatory and legal support of agricultural cooperatives was the approval in 2021 of the "Exemplary rules of intra-economic activity of agricultural cooperatives" [8], which remained unchanged since 2008 and were the cause of additional difficulties in the work of these enterprises.

It is also necessary to take into account the main world trends in the development of rural areas, according to which, it can be predicted that the following areas should become priority for the agricultural cooperation of Ukraine: the production of organic agricultural products, diversification of the economic activity of the village, ensuring the environmental purity of the territories, the restoration of social infrastructure, increasing the standard of living of the rural population [17].

The establishment of the effective functioning of the agricultural cooperative in Ukraine began and was carried out taking into account international norms and rules, so it was possible to predict the successful completion of this process, but the state of war and hostilities stood in the way, which negatively affected all spheres of people's lives. Urgent changes were made to a number of normative legal documents, which caused changes in the interpretation of certain concepts and affected the course of procedures. In particular, this concerns the understanding of force majeure circumstances that occur massively in the specified conditions, and it is impossible to predict all situations, since there is no previous experience.

In the conditions of martial law, for each force majeure circumstance, it is necessary to urgently start negotiations with the counterparty, issue a corresponding certificate at the Chamber of Commerce and Industry of Ukraine, certifying the fact of the event, and perform a number of other necessary actions, which in individual cases will have to be carried out by each member of the cooperative. This refers to cases when an agreement is concluded personally with each member of the cooperative, then each person must receive a certificate of force majeure. It should also be taken into account that not all regional chambers of commerce and industry continue their work during hostilities in the respective territory, so documenting the problem may be impossible.

## CONCLUSIONS

Thus, the modern world and positive Ukrainian experience of the development of agricultural cooperation testify to the inextricable connection of the cooperative movement with the establishment of the principles of the market economy, the free exchange of goods, the spread of open competition, the freedom of foreign economic activity, and the presence of civil society.

At the international level, there is a tendency to consolidate these structures with a simultaneous increase in turnover.

In Ukraine, due to specific shortcomings in the legislative provision of this area, on the contrary, the separation of cooperative members and the creation of separate enterprises is being formed – this is how you can understand the need to conclude personal contracts with each member of the cooperative. This approach prevents the normal operation of Ukrainian agricultural cooperatives in market conditions.

Newly adopted legal acts, the idea of which is to ensure favorable conditions for the functioning of cooperation in Ukraine, along with a positive effect, provoke the emergence of new difficulties, for example, the rules of tax reporting have changed several times during a very short period. In addition, some documents necessary for the proper operation of the agricultural cooperative remain neglected. Among them are the "Sample rules of intra-economic activity of an agricultural cooperative" – they, despite the numerous changes in the legislation of Ukraine, remained unchanged for more than 8 years, and were edited only recently.

Military actions on the territory of Ukraine cause numerous force majeure circumstances. Given the specificity of the legislation and the lack of experience in solving problematic issues in such conditions, the work of all agricultural cooperatives is significantly complicated or stopped altogether.

In general, there have been positive changes in the organization of agricultural cooperation in Ukraine, which gave reason to predict further development, even in the presence of a large number of unresolved problems that remained or arose. However, the hostilities taking place in the territories of traditionally agrarian regions make it completely impossible for cooperation to function in them. Agricultural cooperation in non-combat areas has also suffered as a result of staff shortages, inflation, and recurring force majeure.

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# IMPROVING THE WELFARE OF FISHERMEN ENTREPRENEURS IN NEW NORMAL ERA WITH INCLUSIVE FINANCING MODEL THROUGH VILLAGE CREDIT INSTITUTIONS

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***Abstract***

*The Covid-19 pandemic has had a domino effect on various sectors, both macro and micro. Traditional fishermen in Kedonganan Village (which is a coastal area and a well-known tourist destination in Bali) have also experienced a decline in tourism activities, especially related to limited funding. The purpose of this research is to improve the welfare of fishery entrepreneurs in Kedonganan Village after Covid-19 through an inclusive financing model in the perspective of the Village Credit Institution. This type of research is qualitative research by analyzing data with existing theories to dissect research problems. The data analysis technique used in this research is qualitative data analysis. Based on the results of data analysis, it can be concluded that traditional fishermen in Kedonganan Village feel helped by financial assistance (capital) for individuals, but cannot be given to fishing groups because they do not have formal legal elements. The beneficiary fishermen also stated their readiness to increase their business, one of which was through increasing working time, so that credit installments could be paid. In addition, the assistance of fishing gear facilities and infrastructure (including software applications) as well as institutional empowerment has been able to improve the welfare of fishery entrepreneurs.*

***Key words***: *inclusive financing, new normal era, village credit institution (LPD), welfare*

## INTRODUCTION

Fishing communities have different life characteristics because their lifestyle is formed from life in the ocean that has never been faced by other communities, which have huge risks, especially risks that come from natural factors so that special strategies are needed to work [16]. Other than natural factors, the facilities owned by fishermen are very minimum which makes it difficult to obtain fish catches. This condition causes fishermen to become less prosperous [7]. Therefore, the condition of fishermen's welfare depends on the coastal conditions [8][24]. The difficulty of improving the welfare of traditional fishermen is influenced by some factors, namely the limited quality of human resources, limited ability of business capital and fishing technology information [28], difficulties to diversifying the fishing business, besides that the marketing system for fishery products is more profitable for intermediary traders [9]. In addition, the Covid-19 pandemic has had a fairly large impact, where policies have emerged as an effort to reduce the spread of Covid-19.

The Covid-19 pandemic that has occurred since the end of 2019, and spread to Indonesia in early March 2020, has had a negative impact on the global economy [21]. [10] revealed that this pandemic brings risks to world economic activities including Indonesia, especially in the fields of tourism, trade and investment. The Covid-19 pandemic made a very sharp decline in the tourism sector in Bali in general and in Badung Regency, no exception was Kedonganan Village. Kedonganan Village before the pandemic period was visited by many domestic and foreign tourists. This is because Kedonganan Village is famous for its cafes that stand along the beach which serves menu of very delicious fresh fish dishes, tourists enjoy stunning beach views while having dinner. At the time of the global pandemic that hit the world starting from the end of 2019 which cause no tourists came to Bali, especially Kedonganan Village, so it had a huge impact on the economy of the Kedonganan Village community, not exception the impact on economy of fishing business community in the village. As a result of the decline in the tourism sector, most of the community returned to their fishing business, so financing was needed to overcome the main problems currently being faced. There are many offers of financing, however most of them require terms and systems that cannot be met by fishing communities [6]. In addition, the banking sector also has concerns about the risk of default considering that the income earned by fishermen is uncertain [12]. For the economic life of fishermen to improve, it is necessary to assist in increasing community access to economic institutions, optimizing community institutions into every Government program, integrating informal institutions with formal institutions [17], and activating existing fishing cooperatives to establish new cooperatives with human resources professional managers [29]. An inclusive financing model through the Village Credit Institution (LPD) of Kedonganan Village, this financing is expected to open up new additional business opportunities or to improve the digital marketing system or replace/add equipment currently owned. So that it can have an impact on increasing the welfare of fishing entrepreneurs in Kedonganan Village, Badung Regency, Bali Province. The purpose of this research is to improve the welfare of fishing entrepreneurs in Kedonganan Village, Badung Regency after Covid-19 through an inclusive financing model in the perspective of the Village Credit Institution. Through this research, it is hoped that it will provide a solution to the problems that are currently being faced to improve the welfare of fishing communities on the coast of Kedonganan Beach, Bali.

## MATERIALS AND METHODS

### Welfare Concept

Welfare is a subjective matter, so that each family or individual in it, who has different guidelines, goals and ways of life will give different values about the factors that determine the level of welfare. According to [27], the government's special policy in improving people's welfare to reduce poverty is an integral part of national development which must have a clear development direction. Community welfare is a condition that shows the state of people's lives which can be seen from the standard of living the community [2].

The fishing community is the poorest group of people in Asia and even in the world [3]. The poverty of fishing communities is multi-dimensional and is caused by the non-fulfillment of the basic rights of the community, including the need for food, health, education, infrastructure. In addition, the lack of business opportunities, lack of access to information technology and capital, culture and lifestyles that tend to be extravagant, have weakened the bargaining position of poor community.

### Inclusive Financing Model

Financial Inclusion is an effort to expand public access to financial services. In Indonesia, this financial inclusion program targets the poor community, primarily aimed at saving local businesses and independent businesses by providing cheap, safe and easy access, financial products and services. The financial inclusion program provides the opportunity to access credit and savings safely, and is able to avoid dependence on the poor community from unsafe informal credit sources such as moneylenders [20].

Financial inclusion can be regarded as a process to ensure easy access, availability and use of the formal financial system by all economic actors. Financial inclusion provides various financial services such as savings, credit, insurance, and payments at prices that all economic actors can afford, especially those with low incomes [13]. financial inclusion goals, to achieve economic growth through income distribution, poverty alleviation and the achievement of the financial system [1]. Financial inclusion according to [14] is aimed to attract "unbanked population" in the formal financial system, while Chakravarty and Pal (2013) are more interested in the process of removing barriers and overcoming the incapacity of disadvantaged groups. According to [5], financial inclusion is a multidimensional and diverse phenomenon in each region or every sector. On the other hand, financial exceptions can also occur due to obstacles from the company itself such as asset ownership and business guarantees.

**Definition and Role of LPD Financial Inclusion**

Village Credit Institutions (LPD) are financial institutions belonging to Pakraman Village domiciled in Pakraman Village area (Bali Governor's Regulation Number 44 of 2017). LPD has a business field that includes receiving and collecting funds from village communities in the form of *Sesepelan* funds and *Sepelan* funds, providing credit to rural and rural communities, providing credit to other village communities with inter-village cooperation referring to the Bali Governor Regulation and with applicable conditions. LPD's operational activities are also related to receiving loans with a maximum amount of one hundred percent of the total capital including reserves and retained earnings from financial institutions, excess liquidity is deposited in a designated bank with adequate services and competitive interest in return. In carrying out its line of business, it must comply with the prudential principles of LPD management as regulated in the Governor's Regulation (Bali Provincial Regulation Number 3 of 2017).

The unique and autonomous nature of the LPD is oriented towards strengthening the social, cultural and economic life of the Balinese indigenous people. This unique nature is shown because LPD only refers to local policies and is not subject to central government policies [19]. Although not included in the bank's financial institution, the Village Credit Institution (LPD) still has the role of financial inclusion in Bali's economic development. For this reason, LPD as a microfinance institution deserves priority attention from various stakeholders in its efforts to increase its financial inclusion role for Bali's development [4].

**Method**

This research is a type of qualitative research by analyzing data with existing theories to dissect research problems. The research location was conducted in Kedonganan Village, Badung Regency, Bali Province, which is a coastal area and most of them work as fishermen. The data analysis technique used in this research is qualitative data analysis. According to [11] qualitative method can be interpreted as a problem solving process that is investigated by describing current state of the subject and object of research, based on the facts that appear or as they are. Miles and Huberman in [25] argued that the activities in qualitative data analysis were carried out interactively and took place continuously until they were completed so that the data was saturated. Data collecting in this study was carried out through in-depth interviews and Focis Group Discussion (FGD) with fishermen and community leaders in Kedonganan Village.

## RESULTS AND DISCUSSIONS

In daily life of Kedonganan fishing entrepreneur community, the Traditional Village also has a very influential role in the life of Kedonganan fishing community. The role of Traditional Village in this case, as mentioned earlier, is there a kind of called Awig-Awig or some kind of law or regulation that must be obeyed and followed by the fishing community in Kedonganan, that the purpose of making this awig-awig is to provide guidelines for behavior of the fishermen. fishing communities in social life, especially in carrying out fishing activities and to maintain the unity of the Kedonganan fishing community itself. In addition, currently Kedonganan fishermen get loan assistance through the Village Credit Institution [26].

In Kedonganan Village itself there is a Village Credit Institution (LPD) which is managed by the Traditional Village. However, in 1995 the Kedonganan area had begun to be touched by the development of tourism. The existence of

Kedonganan Beach as a fishing center in Badung is seen by the community as an opportunity to develop. The opportunities seen are also comfy promising, namely culinary tourism. From here then stood the cafes that specifically provide a menu of seafood dishes with all its variations along the Kedonganan beach. The next role of the Traditional Village LPD in Kedonganan Village is to develop a Kedonganan Beach arrangement program. The program which later became a village program began to be implemented in 2007. Since 2007 the Kedonganan Traditional Village has been supported by the Badung Regency Government [23].

Actually, not only cafes where LPD provides support, but LPD also provides support to fishing communities, for example by providing productive credit loans to fishing communities. One example of fishermen who received credit assistance from LPD Desa Adat are Mr. Wayan Artha and Mr. Made Gita Adnyana, Kedonganan fishing communities who received loans from LPD for the purpose of buying fishing equipment such as nets, boats *(jukung)*, and others.

The community of Kedonganan Village are starting to experience changes, which will be explained further about what changes have occurred in Kedonganan, especially changes that have occurred in Kedonganan fishermen. Where the utilization of tourist attractions and the management of cafes in Kedongan as well as assistance from the Kedonganan Traditional Village LPD can change the lives of Kedonganan fishermen, one of which is that the fishermen in Kedonganan for now are not fishermen who go to sea but fishermen who already have crew members [22]. The change in economic life for the better is a change in life in fulfilling the daily economy of a fisherman family whose connotation is called poor but is able to become the owner of seafood grilling services, cafe manager and even become a fisherman who has employees. The changes in economic life experienced can be a motivation in the lives of other fishing communities [30].

Financial inclusion can be regarded as a process to ensure easy access, availability and use of the formal financial system by all economic actors. In financial inclusion, various financial services are available, such as savings, credit, insurance, and payments at prices that all economic actors can afford, especially those with low incomes [13]. Although not included in the bank's financial institution, the Village Credit Institution (LPD) still has the role of financial inclusion in Bali's economic development. This is evident from the LPD's financial inclusion index, which is mostly above 0.50 points. The financial inclusion policy has been intensified in recent years by policy makers. Even the Ministry of Finance and Bank Indonesia have announced that one of the policies that will be taken to help the country of Indonesia get out of the middle-income trap is through a financial inclusion policy. For this reason, LPD as a microfinance institution deserves priority attention from various stakeholders in its efforts to increase its financial inclusion role for Bali's development [4].

Based on the results of the Focus Group Discussion (FGD) which was held on July 23, 2022 at the Sea Breeze Bangsal Cafe with a group of Balinese Men Fishermen on the Beach of Kedongan Village, to find out strategies to improve the welfare of fishing entrepreneurs in Kedonganan Village, information was obtained from several competent sources such as The head of the fishermen group and the management of the fishermen group as well as the members of the fishermen group are as follows.

***(1)Capital***

In terms of capital, the Kedonganan Village Credit Institution (LPD) provides working capital credit to fishermen entrepreneurs individually, to be used to buy fishing gear equipment, such as *jukung*, machines and nets. This is very helpful for fishermen during the pandemic and after the endemic period enters the new normal era, so that these fishing entrepreneurs can still survive and develop their businesses in the midst of difficult situations. However, the working capital assistance or credit provided is still individual, which still requires guarantees or collateral from the fishermen. While the provision of working capital assistance to fisherman groups as an institution has not been realized, the provision of business credit in groups is highly expected by the chairman and members of the fishing groups in Kedonganan village. One of the fishing groups in Kedonganan, namely the Putra Bali fishermen group, coordinated by Mr. Made Gita Adnyana, has a cafe business on the Kedonganan beach that sells fish dishes caught by the fishermen. This fishing group business requires working capital assistance from the LPD. They expect to receive business credit assistance from the LPD of Kedonganan Village. Because at this time of endemic cafes selling fish dishes on Kedonganan beach have begun to be crowded with domestic and foreign tourists.

***(2)Community Empowerment or Human Resources***

Based on the results of Focus Group Discussion (FGD) with the fishing community of Kedonganan Village, information was obtained about counseling and training that is often provided by the local government, such as training on business management, field counseling, training on marketing and fish processing from the local government of Badung Regency. In addition, counseling about small fish farming is also expected, it is hoped that through improving management skills and other expertise, it is hoped that fishermen in Kedonganan village will be able to innovate businesses other than as fishermen. Through this innovation, fishermen can increase their income and in the end will be able to increase their income and ultimately improve their welfare [18].

Furthermore, the local government also issued the Bali Province Regional Regulation Number 11 of 2017 concerning Bendega. Bendega is a traditional institution that is socio-cultural and religious. Bendega is engaged in the economic, social and cultural fields. Meanwhile, in the field of fisheries, Bendega is part of traditional Balinese culture. Bendega which is part of traditional Balinese culture plays a role and functions to improve the welfare of Krama Bendega and is based on the Tri Hita Karana philosophy and the teachings of Hinduism in Bali.

***(3)Strengthening fishermen's institutions in Kedonganan Village***

According to the Kedonganan Village profile data, the number of fishermen currently available is approximately 257 people. The number of Kedonganan fishermen are members of four Kedonganan fishing community groups. The four fishing groups are: 1) The Putra Bali Fisherman Group (KNPB), 2) Kertha Bali Fisherman Group (KNKB), 3) Ulam Sari Fisherman Group (KNUS), and 4) Segara Ayu Fisherman Group (KNSA). According the four groups of fishermen, only two of them have a legal protection, there are Putra Bali Fisherman Group and Kertha Bali Fisherman Group. After the inauguration of Putra Bali Fishermen Group in 2012 and for the sake of fast administration of Putra Bali Fishermen Group in Badung Regency, finally the Putra Bali Fishermen Group has a valid decree from the Head of the Badung Regency Fisheries Service which the decree was issued considering the application letter of Putra Bali Fisherman Group Number 02/KNPB/XI/2016, dated November 10, 2016 regarding the request for ratification. The results of these considerations need to determine the Regent's decision on the Dynamics of the Socio-Economic Life of Fishermen in Kedonganan Village, Badung Regency 1990-2018. With the existence of these 4 groups of fishermen, it is hoped that fishermen will have strong institutions in developing their businesses, such as marketing fish products, counseling and business assistance as well as providing capital assistance and infrastructure through existing fishing groups.

The Fish Auction Place (TPI) located in Kedonganan is one of the places for Kedonganan fishermen to sell their catch. The TPI was basically one of the aids provided by government with the aim that Kedonganan fishermen were protected from the bondage system at that time. The TPI located in Kedonganan Village was inaugurated on March 11, 1979, the TPI has an important role in helping the marketing of Kedonganan fishermen [15].

***(4)Facilities and Infrastructure***

From the infrastructure side of the production process, in this case fishing gear, fishing technology Fishermen in Kedonganan village are assisted by the Badung district government by providing assistance with fishing gear such as machines, fiber and nets through fishing groups. In addition, the Fish Go application is also provided, which is an application designed to help fishermen map fish species in their catchment areas. This application was designed by I Gede Mertha Yoga Pratama and friends, a Bachelor of Marine Science from Udayana University. This application can help fishermen to optimize their catch. So that it can help improve the welfare of fishermen, especially in Kedonganan Village and throughout Indonesia in general.

***(5)LPD and Financial Inclusion***

Based on the results of information processing, there are several important information that can be stated, as follows.

(a)LPD as a micro-economic financial institution belonging to the Traditional Village, is under the supervision of the LPD formed by the Traditional Village apparatus.

(b)In general, LPD's have sufficient access to assist rural communities in the financial sector.

(c)Individually, community who need loans still complain about loans that must be accompanied by collateral/collateral.

(d)In groups it has not been able to be implemented because the institutions assisted by the LPD are in form of structuring business premises, additional capital has not been realized through groups because the groups have not been formed formally.

(e)All customers hope that the credit payments that are temporarily charged are flat, they hope that it will be more flexible according to the income they get.

(f)All fishermen who receive capital assistance from LPD agree that they can increase their business both in creating additional working hours /work opportunities and income.

## CONCLUSIONS

Strengthening efforts to improve the welfare of traditional fishermen in Kedonganan Village can be done by providing financial assistance from the Village Credit Institution (LPD) individually or as an institution so that fishermen can feel financial assistance without feeling burdened with complicated requirements. Improving the empowerment of human resources (HR) by increasing the skills of fishermen entrepreneurs through business management training, counseling and business assistance. Strengthening fishermen's institutions through fisherman groups by providing capital assistance, training and infrastructure assistance from the local government of Badung Regency through fisherman institutions that already exist in Kedonganan Village. Provision of assistance for fishing gear facilities and infrastructure using modern application technology such as the Fish Go application, so that fishermen are able to optimize catches and carry out business innovations so that they can also improve the welfare of fishing entrepreneurs.

LPD as a micro-economic financial institution belonging to the Traditional Village has access to assist village communities in the financial sector individually, but as a group it has not been able to be implemented because the institutions assisted by LPD are in the form of structuring business premises, additional capital has not been realized through groups because the group has not yet been formed formally. All fishermen who receive capital assistance from LPD agree that they can increase their efforts both in creating additional working hours and income, and hope that credit payments currently charged are flat and more flexible in accordance with the income earned.

The implementation of the financial inclusion program from the Village Credit Institution (LPD) of the Kedonganan Traditional Village requires policy support from the Traditional Village and the local government to work together to improve access and use of LPD services, namely by increasing every dimension of government financial inclusion and so that the Village Credit Institution can provide cheap credit. and easily accessible to fishing entrepreneurs who need cheap working capital with uncomplicated requirements. In an effort to improve the welfare of fishermen in Kedonganan Village, there must be business innovations such as coastal tourism businesses, culinary businesses and fish processing businesses. With technological advances in marketing the catches of fishermen, they should be market not only conventionally but also digitally marketing or marketing fish by online. It is hoped that there will be a synergy between the Regional Government, the Kedonganan Traditional Village and the Village Credit Institution (LPD) as well as the private sector in establishing partnerships with fishing entrepreneurs so that they are able to develop their businesses well, so that the welfare of fishermen can be improved.

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# HAPPINESS AND PROFITABILITY UNDER PHILIPPINE RICE TARIFFICATION LAW: REGRESSION AND *K*-MEANS CLUSTERING APPROACH

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***Abstract***

*Good economic profitability in rice farming is known to have a positive influence on the happiness or well-being of farmers. This study investigated the relationship between profit and happiness of rice farmers in Leyte, Philippines under the carrying out of Rice Tariffication Law (RTL) in the country. The study employed cross-sectional and secondary data from an existing study from rice farming literature that measures the profit and corresponding happiness of a farmer in one cropping season. Regression modeling was used to elucidate the correlation between profit and happiness, and K-means clustering was employed to categorize a group of farmers that have more or less the same characteristics. Results showed that, on average, profit and happiness are relatively low during the implementation of RTL. The bivariate linear regression model has shown that there is a positive relationship between profit and happiness. This implies that as profit increases, the happiness of a farmer also increases. In addition, the logistic regression has revealed that the likelihood of a farmer being happy increases by 0.324% when the profit increases by 1%. Moreover, the ordered logistic regression has shown that as profit increases by 1%, farmers' log odds of being happy increase by 0.0129. Furthermore, by K-means clustering, the dominant of the farmers (45.76%) are grouped as low profit and happiness, and only 7.91% are categorized as high profit and happiness under RTL. Hence, the study recommends that the Philippine government must subsidize the local farmers' needs to increase their economic profit and improve their well-being as a farmer.*

**Key words**: *happiness, economic profit, rice tariffication law, regression model, k-means clustering*

## INTRODUCTION

Happiness is not only defined as the individual's conditions of economic prosperity but also refers to the condition of a great and meaningful life [7], [8], [24]. Measuring happiness is scrutiny of subjective well-being and meaning of life of an individual and it is highly studied in the area of social sciences. In particular, there are researches in economics that deals with the relationship between happiness and income [9], [10], [11], [19], [23]. In fact, some social scientists are puzzled about the correlation between these two variables since their relationship is very dynamic across different demographic profiles and life management [12], [19], [21]. On the face of it, happiness research is considered intriguing and interesting to social scientists due to its fluctuating behavior as a function of income inequality. Apparently, studying the economic predictors of happiness will understand the nature of an individual's well-being which is a function of different life events and life profiles [12].

In particular, in the study of Kumar et al. [13], income and satisfaction in life events are strong predictors of farmers' happiness. Income or profit is the main reason why an individual is motivated to work. In fact, good business performance is determined by higher economic profitability. However, during the time that Rice Tariffication Law (RTL) was implemented in the Philippines, profitability (or income) and satisfaction in rice farming has an inverse effect on each other [4]. This means that a farmer with a high income tends to be more unhappy due to corresponding high agricultural expense that leads them to access credit. Apparently, the country Philippines is an agricultural economy where rice is the main crop and main source of income for many Filipinos. In fact, the Philippine government is focusing on the agricultural sector, especially for rice as

Filipinos' main staple food to progress by making programs and laws, and one of them is RTL. RTL was issued in the year 2019 and was destined to lift the import restriction of rice in the country [4], [20], [25]. The main purpose of RTL is to allow the importation of rice to meet the required supply for all Filipinos which offer customers rights and affordable rice prices, especially to the poor [3].

However, the rice output price in the country has lower down due to the high supply. In that case, rice farmers' profitability is adversely affected as well as their well-being or happiness in farming. The most affected by RTL are small-scale (poor) farmers in the rural areas of the country. According to the paper of Briones [2], RTL is worsening the income inequality in the Philippines where rice farmers are experiencing economic poverty. In fact, there are studies in rural areas in the Philippines that rice farmers are having a hard time compensating for their expenses in farm inputs due to the low marketability profit of rice outputs [3], [4], [20]. In addition, aside from the low price of rice outputs, farmers are also facing difficulties in acquiring agricultural inputs since their prices are also rising over time [4], [6].

Although the investigation of happiness and profitability is well-research in the economics literature, however, the relationship between these two variables concerning rice farmers experiencing the implementation of RTL in the Philippines has never been done. In fact, elucidating the association of the said variables using the regression analysis and *K*-means clustering approach is scarce. In light of it, this correlation study is realized. Generally, the purpose of this study is to explain the features of the relationship between happiness scale and profitability in rice farming under RTL in Leyte, Philippines. Specific objectives are as follows: (1) construct a regression model for happiness and profitability of rice farmers in one cropping season under RTL, and (2) create clusters or groups with the same characteristics in regards to the correspondence between happiness and profitability in rice farming under RTL using *K*-means clustering approach. The significance of this study is to provide richer information that may help policy-making bodies in the government in improving the productivity and well-being of small-scale rice farmers in the Philippines.

## MATERIALS AND METHODS

In this study, a complex-correlational research design was employed to elucidate the influence of the level of profitability in rice farming on the happiness of farmers. The study considered secondary data from the study of Casinillo and Seriño [6]. The study deals with predicting the determinants of happiness using econometric modeling, however, it does not focus on the effect of profit on the subjective well-being (happiness scale) of farmers under the RTL, particularly, in Leyte, Philippines. In that case, the following variables were considered: (1) happiness (scale of 1 to 10) and (2) profit in one cropping season under the implementation of RTL (in PHP). Table 1 presents the interval happiness perception scores and their corresponding verbal description.

Table 1. Happiness perception scores and their verbal description

| Perception Score | Description |
|---|---|
| 1.00 - 2.80 | Not Happy |
| 2.81 - 4.60 | Slightly Happy |
| 4.61 - 6.40 | Moderately Happy |
| 6.41 - 8.20 | Happy |
| 8.21 - 10.00 | Very Happy |

Source: Authors' own guidelines (2022).

Moreover, the study employed 177 respondents in Leyte, Philippines as small-scale (mean paddy farm area is 0.71 hectare) rice farmers that have experienced the effect of RTL in the remote area of the country.

As for data analysis, the study dealt with regression modeling to determine the association of the said two variables. Henceforth, the regression model can be written as:

$$\text{Happiness}_i = \partial_1 + \partial_2 \log{(\text{profit} + 1)_i} + \varepsilon_i$$

where: $\text{Happiness}_i$ refers to the level of happiness (scale of 1 to 10), $\log{(\text{profit} + 1)_i}$ refers to the logarithm (base of 10) of profit (in PHP) plus 1 (normalized), $i = 1, \dots, n$ and $n$ refer to the number of rice farmers, $\partial_1$ and $\partial_2$ refers to the parameters to be approximated and $\varepsilon_i$ captures the remaining random error in the model. Firstly, ordinary least square (OLS) regression was considered as the dependent variable happiness scale (1-10) was used. The OLS model will approximate the increase (or decrease) of the happiness level as the profit increases (or decreases) [22].

Secondly, the binary logistic model was constructed by transforming the dependent variable as follows: 0 - not happy (scale of 1 to 5) and 1 - happy (scale of 6 to 10). The logistic model determined the association between dependent and independent variables in terms of the log of odds [17]. Additionally, in the binary logistic model, the marginal effect was computed to determine the probability of binary outcome (dependent variable) change as the predictor also changes [18]. Thirdly, the ordered logistic model was also employed by decoding the dependent variable as follows: 0 - not happy (scale of 1 to 3), 1 - moderately happy (scale of 4 to 6), and 2 - very happy (scale of 7 to 10). This model also elucidates the relationship between dependent variables (ordinal categories) and their predictors concerning the ordered log-odds scale[17], [22].

Moreover, the *K*-means clustering method was used to cluster or group that data set into similar categories. This approach aims to partition a data set of observations (correspondence between happiness scale and profit in PHP) into different clusters (*K*). Note that the *K*-means clustering approach uses centroids, that is, the *K* different random points in the data were assigned to clusters with the nearest centroid.

As for optimizing the value of *K*, the approach uses the sum of squared errors or variation by comparison [14], [15].

All statistical calculations and graphs are done with the aid of software programs called STATA and R-statistics.

## RESULTS AND DISCUSSIONS

This section discusses the behavior of the relationship between happiness and profitability of rice farming as an influence of RTL. The correlation of these two variables is vital in rice production as well as the farmers' efficiency and well-being. Perhaps, elucidating the relationship between these two variables may suggest a plan of action or policy that will improve or modify the promulgated RTL in the country which favors the affected and poor rice farmers. Figure 1 presents the scatter plot of subjective happiness (Scale of 1 to 10) and economic profit in rice farming for one cropping season (in PHP). The graph shows that the impact of RTL on the well-being of farmers is somewhat negative showing a low level of happiness which corresponds to low economic profit for most of the farmers.

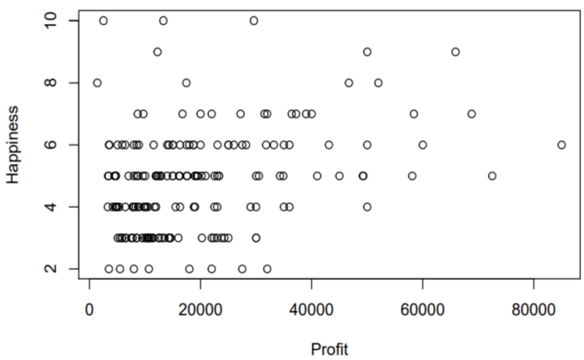


Fig. 1. Scatter plot for happiness and profit of farmers
Source: Authors' own construction based on data (2022).

This means that farmers' well-being is adversely affected by low prices of rice outputs due to the volume of imported supply brought by the RTL [20]. According to Calicdan et al. [3] and Casinillo [4], most of the small-scale rice farmers' well-being is negatively affected because of low income from rice production during the implementation of RTL. This is because several of the rice farmers in the rural areas are not supported by the Philippine government concerning their farm inputs while suffering from low prices of outputs [25]. Hence, Fig. 1 only shows a few rice farmers that are happy during the promulgated RTL in the country. Table 2 shows that the mean subjective happiness of rice farmers is considered low (4.85 out of 10) (SD=1.67), in particular, it can be interpreted as "moderately happy" based on Table 1. In addition, the average profit of farmers in one cropping season is close to PHP 19,607.70 (SD=15,222.69) and is considered relatively low as opposed to no existing RTL in the country. This result is parallel to the study of Casinillo and Seriño [6] which stated that the actual happiness in rice farming is low compared to their expected happiness under the RTL. It is worth noting that in some studies, happiness or well-being is directly related to income and productivity [4], [10], [19], [23]. In other words, the happiness of an individual is dependent on their economic gain and satisfaction as being productive in their work. Moreover, the result suggests that lower income (or profit) is associated with the worst feeling (stress) and not being satisfied with their life experiences [10], [21].

Table 2. Descriptive statistics

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Happiness[a] | 4.85 | 1.67 | 2 | 10 |
| Profit[b] | 19,607.70 | 15,222.69 | 516 | 85,000 |

Note: a - Scale of 1 to 10, b - one cropping season (in PHP)
Source: Authors' own calculation based on data (2022).

**Regression analysis**

Regression analysis was constructed to explain the behavior of the relationship between happiness and profitability of rice farmers. However, before the interpretation of the constructed regression models, diagnostic tests were employed first. In that case, the model is considered heteroscedastic by the Breusch-Pagan test ($\chi^2$ =8.26, p-value=0.0041). Hence, the model is corrected using the robust command in STATA to have the constant residuals in the model and eliminate the biased caused by standard errors [5]. With the aid of the Shapiro-Wilk test, it has been shown that the OLS model's residuals are not normal (W=0.96, p-value<0.001). However, the graph of Kernel density estimate for residuals in the model and the normal density is almost the same as shown in Figure 2, that is, the residuals of the regression model are almost normal [22]. On the face of it, the regression models are valid for concluding the relationship between happiness and profitability of rice farmers under the promulgated RTL as shown in Table 3.

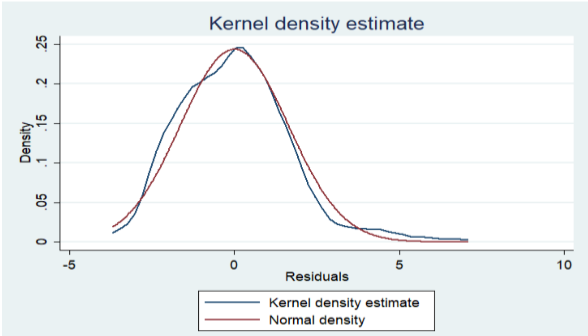

Fig. 2. Kernel density estimate and normal density for residuals
Source: Authors' own construction based on data (2022).

Fig. 3 (happiness versus actual profit) and 4 (happiness versus normalized profit) show that the regression line is increasing in nature. This implies that as profit increases, the happiness or well-being of a farmer will also increase. In other words, the happiness of a farmer that is associated with productivity is directly proportional to the economic profit which they get through farming. It is worth noting that income (or profit) will bring benefits and comfort to the farmers' families [6]. In fact, several studies in the literature have studied the relationship between happiness and income, in which they found a positive relationship between the two variables [6], [9], [11].

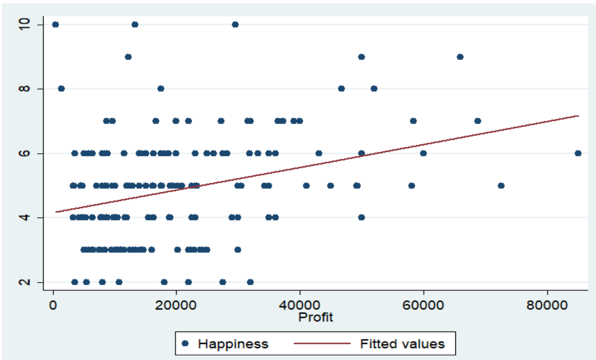

Fig. 3. Regression line as fitted values to the actual values of profit
Source: Authors' own construction based on data (2022).

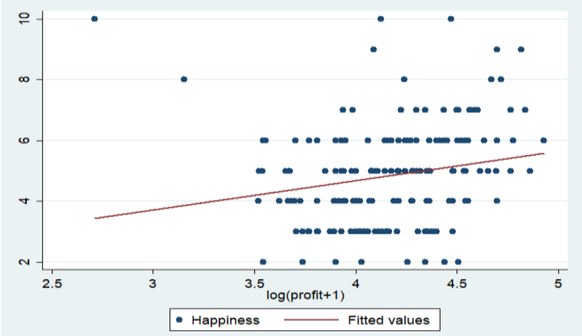


Fig. 4. Regression line as fitted values to the normalized profit
Source: Authors' own construction based on data (2022).

Table 3 reveals that OLS model is significant at 10% level ($F_c$=2.76, p-value=0.098). Additionally, it reveals that economic profitability is a significant predictor of the happiness of a farmer under the implementation of RTL at a 10% level. This implies that as profit increases by 1%, there is a significant increase of 0.0096 in the level of happiness in farming. In that case, farmers' well-being and motivation are to maximize their profit and improve their productivity in the paddy farm. This finding is parallel to the existing studies on the economics of happiness that income (or profit) is a significant predictor of an individual's subjective happiness [1], [7], [9]. The goodness of fit indicates that only 4% of the variability in the response variable is explained by the model. This low increment in happiness in relation to their economic profit can be explained by the effect of RTL. In the study of Casinillo [4], farmers have low satisfaction in their work due to the low marketability price of rice outputs and expensive agricultural inputs. Moreover, the binary logistic model is significant at a 1% level ($\chi^2$=9.19, p-value=0.002). This implies that profit as a predictor of happiness is significantly influenced. In fact, the model reveals that in every 1% increase in the profit, there is a corresponding increase of 0.0151 log odds of being a happy farmer and it is significant at a 1% level. In addition, by marginal effects, the model reveals that the probability of a farmer with high profit being happy is higher by 0.324% as opposed to a farmer with low profit. In other words, a farmer who has a good profit during the implementation of RTL is more likely to be happy. Furthermore, the ordered logit model is also significant at a 1% level. This indicates that profit is a significant predictor of (p-value=0.006) happiness.

The model depicts that as the profit increases by 1%, farmers are more likely happy. The results suggested that the main target of a farmer is a good profit that will compensate for their expenses and hard work. The same results in the existing studies in literature, the farmers' well-being (or happiness) is directly associated with their economic gain (or profit) [4], [16]. In the study of Casinillo [6], farmers must be supported by the government in relation to their agricultural needs and expenses to maintain the rice farmers' productivity in the country. In that case, farmers' economic profit will tend to increase as well as their well-being if they are supported and allocated with a budget as subsidies for farm inputs.

Table 3. Regression analysis for happiness and profitability

| | **OLS Model** | **Binary Logit Model** | **Ordered Logit Model** |
|---|---|---|---|
| Constant | $0.822^{ns}$ (2.450) | -7.086** (2.214) | - |
| log (profit$^b$+1) | 0.966* (0.582) | 1.510** (0.522) | 1.286** (0.476) |
| n | 177 | 177 | 177 |
| F | 2.760 | - | - |
| $\chi^2$ | - | 9.19 | 7.56 |
| p-value | 0.098 | 0.002 | 0.006 |
| $R^2$ | 0.040 | - | - |
| Pseudo $R^2$ | - | 0.041 | 0.023 |
| Marginal effects | - | 0.324 | - |

Note: b - one cropping season (in PHP); Standard errors are enclosed by parenthesis; ns - not significant; *p<0.1; **p<0.01.
Source: Authors' own calculation based on data (2022).

## *K*-Means Clustering

Table 4 shows the *K*-means clustering results with the optimal solution *K*=4. This implies that the data set can be clustered into four groups with the same characteristics. Cluster 1 shows the highest mean average of happiness (Mean=6.43) and profitability (Mean=PHP 58278.57) in rice farming in one cropping season under RTL. This group of farmers is happy (Table 1) and productive in rice farming even with the adverse effect of RTL on the rice output marketability price. Such group of farmers are considered the least affected by RTL, or somewhat the government has supported their agricultural inputs and other expenses [3]. However, this actual happiness is significantly lower as opposed to the expected happiness in relation to the implemented RTL [6]. The second cluster represents the group of moderately happy farmers (Mean=5.41; Table 1) to their profit (Mean=PHP 33,548.28) under RTL. This type of farmer is moderately affected by the implemented RTL in which their profit and happiness are lowered compared to the previous cropping season (non-existence of RTL). As for the third cluster, farmers of this group can be interpreted as moderately happy (Mean=4.79; Table 1) which corresponds to a profit of PHP 19,170.94. Farmers of this type are approximately the same as cluster 2 (moderately happy), however, a little lower is observed due to the big difference in economic profit. The last group (cluster 4) of farmers is the most affected by RTL and can be represented as slightly happy (Mean 4.41; Table 1) farmers with an economic profit of PHP 8,218.56.

Table 4. *K*-Means clustering for happiness scale and profitability in rice farming (n=177)

| Cluster (*K=4*) | Descriptive Statistics | Happiness[a] | Profit[b] |
|---|---|---|---|
| 1 | n | 14 | 14 |
| | min | 4 | 46,700 |
| | mean | 6.43 | 58,278.57 |
| | max | 9 | 85,000 |
| 2 | n | 29 | 29 |
| | min | 2 | 27,200 |
| | mean | 5.41 | 33,548.28 |
| | max | 10 | 45,000 |
| 3 | n | 53 | 53 |
| | min | 2 | 14,000 |
| | mean | 4.79 | 19,170.94 |
| | Max | 8 | 26,000 |
| 4 | N | 81 | 81 |
| | Min | 2 | 516 |
| | Mean | 4.41 | 8,218.56 |
| | Max | 10 | 13,500 |

Note: a - Scale of 1 to 10, b - one cropping season (in PHP)
Source: Authors' own calculation based on data (2022).

This type of farmer is dominant among all farmers who experience the effect of RTL in the Philippines [2], [3], [4], [6], [20], [25].

In light of it, the happiness and profitability of rice farmers in the rural areas in the country are negatively lowered when there is a continuous importation as the government sustains the economic supply for rice.
Figure 5 depicted a graphical representation of *K*-means clustering results with different colors that categorized the different clusters or groups of farmers with the same characteristics. Only 7.9% (color green) of the farmers in Leyte are considered happy as shown in Figure 5. About 16.38% (color red) and 29.94% (color mint blue) of the farmers can be represented as moderately happy (Figure 5). Dominantly, on average, 45.76% (color blue) of these farmers are considered as slightly happy to their profit under RTL (Figure 5). Overall, the figure shows that the effect of RTL in rice farming in rural areas in the country the Philippines is adverse and has affected the well-being and productivity of farmers. This result is consistent with the existing studies in the literature [2], [4]. On the face of it, the poor farmers must be supported by the Philippine government to progress rice production in the country [26].

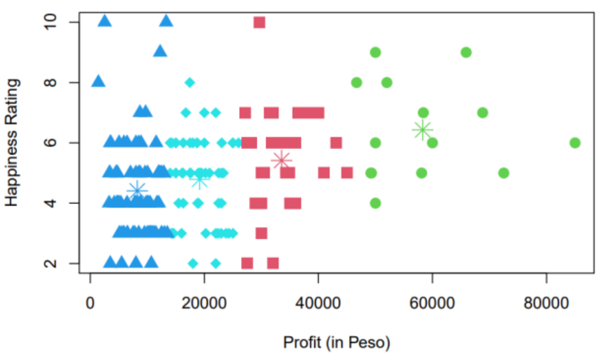


Fig. 5. *K*-means clustering results with *K*=4
Source: Authors' own construction based on data (2022).

## CONCLUSIONS

The study's purpose is to elucidate the association between the happiness and profitability of rice farmers in a rural areas in the Philippines under the promulgated RTL. The study revealed that the level of happiness in rice farming during the RTL is relatively low as well as the profitability.
This implies that RTL harms farmers' productivity due to the high agricultural input

costs and low marketability price of rice outputs in the country.

The regression analysis has depicted that profitability is a significant predictor of happiness in rice farming under RTL. Additionally, it is revealed that happiness is directly associated with economic profitability. Hence, it is concluded that as profit increases, rice farmers are more likely to be happy.

However, the increase in happiness is just a little due to the low profitability in farming (one cropping season) under RTL. In addition, the *K*-means clustering has revealed that the dominant rice farmers have a low level of happiness that corresponds to a low level of profitability due to RTL and very few are in the category of happy farmers with high profit. Conclusively, the Philippine government must take an action to modify the promulgated RTL in the country that will favor the small-scale rice farmers, especially in remote areas. The government also must allocate a budget for subsidies and support to the poor farmers concerning their agricultural inputs as well as farm equipment that somehow helps their productivity and profitability under RTL. Moreover, the local government must conduct seminars and training on how to be efficient and productive (e.g. Farmer Field School) in rice farming as well as orientation about the advantages and disadvantages of the implemented RTL in the country. The study recommends that one may consider conducting a study that involves farmers' cooperatives and access to credit as a potential gap in the argument of this current study for future research.

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# ECONOMETRIC ANALYSIS ON RICE FARMERS' INCOME AS INFLUENCED BY EXTENSION AGENT'S ROLE

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***Abstract***

*This article aimed to present the role of extension agents in improving rice farmers' income in Albuera, Leyte, Philippines. It also predicts the significant factors that influence the rice farmers' income to make policies that might improve the well-being of farmers as well as their rice production. Primary data were gathered through a developed structured questionnaire as a guide for a face-to-face interview of the sample farmers. The gathered data were summarized through some descriptive statistics and constructed an inference using econometric analysis in the form of a regression model. Results depicted that the average monthly income of rice farmers in Albuera, Leyte is close to 5,047.95 (₱) (SD=2,208.20 (₱)). On average, farmers' perception score towards extension agents' role revealed that they are "undecided" (Mean=3.28; SD=0.85) (score of 1 to 5) in regards to satisfaction. Additionally, the econometric model showed that farmer's ownership of the rice field (p-value=0.003), educational attainment of farmers (p-value=0.001), perception of farmers to extension agents as "organizers" (p-value=0.100), and perception of farmers to extension agent as "facilitator" (p-value=0.080) are the significant predictors of their monthly income. In conclusion, farmers in Albuera need assistance in regard to their agricultural production especially knowledge about new technologies and innovation to increase their economic profit. Hence, the study recommends that the Philippine local government must initiate organizing farmers' associations and cooperatives to address farmers' constraints and lack of agricultural training. Furthermore, the agricultural sector in the country must strengthen the agricultural extension agents by giving them proper training and education to effectively aid farmers.*

***Key words***: *extension agent, small-scale rice farmers, monthly income, econometric analysis*

## INTRODUCTION

The role of an agricultural extension agent is to improve the agricultural production process, develop education in agriculture, and progress farmers' income [24], [14]. In that case, sustainability in the agricultural aspect is expected to grow when an extension agent is continually providing the information and right knowledge for innovation. Hence, an extension agent is vital especially for small-scale farming to increase productivity. In the country Philippines, rice is the main staple food and source of income for Filipinos living in rural areas [5], [7]. And most of the rice farmers are low educated individual that needs proper guidance in the aspect of the farming system [3], [7]. The study of Casinillo and Seriño [7] revealed that farmers without enough knowledge and expertise in the government agricultural policy have a low happiness that affects their level of production. As a consequence, rice farmers' satisfaction and income are adversely affected by their low quality of well-being and lack of knowledge in agriculture [5], [23], [28]. On the face of it, the government must initiate agricultural programs and projects that will enhance productivity in farming through extension agents [8]. With this, non-educated farmers are guided and provided agricultural techniques to improve their capability in farming and increase profitability. In the study of Okwuokenye and Okoedo-Okojie [21], extension agents in agriculture have a primary concern about innovative technologies for farmers that will help them solve problems and amend existing techniques. In fact, agricultural extension is a kind of educational procedure that is fashioned for farmers to adopt improved technologies and practices [20], [30]. In that case, an extension agent is described as a tool in the carrying out of different agricultural projects [24], [14], [30].In other words, the main purpose of an extension agent is to impart educated agricultural techniques that will sufficiently increase the production level and increase farmers' income [2].Apparently, in the study of Birkhaeuser et al. [3], it is stated that the extension agent has induced a great modification in the production and highlighted the value of an efficient transferral of advanced knowledge and new techniques to the farmers. Additionally, an agricultural extension agent can bridge the gap between discoveries in science laboratories and modification in the farmer's actual situation in the field [30], [3]. Extension agents' roles are the following [17]: (1) Educator - this refers to disseminating or transferring of information that brings about positive modification or benefits to farmers through pieces of training; (2) Mediator - this means that extension agents serve as a linker between agricultural researchers and actual farmers; (3) Organizer - this refers to a systematic planning and coordinating groups or associations to obtain a common goal which is agricultural productivity; (4) Facilitator - extension agents serve as a guide for farmers in facilitating their needs especially and addressing agricultural constraints; (5) Solution giver - this means that an extension agent must have enough knowledge and always been a source of information for farmers' existing problems in the production, and (6) Enabler - this refers to making the farmers being capable of coping the situations and achieving goals which are improving productivity. Shedding light on the level of rice farmers' income is well-researched, however, elucidating the role of extension agents as correlates of farmers' income is scarce in the body of knowledge. Additionally, predicting the factors (role of extension agents) affecting the farmers' income using an econometric analysis has never been done especially in the rural areas in the Philippines. Hence, this article constructed a regression model that determines the significant factors that influence the farmers' income in rice farming as influenced by extension agents. Specifically, the article provides an answer to the following objectives: (a) to describe the socio-economic profile of rice farmers in Albuera, Leyte, Philippines; (b) to find out causal factors that influence the rice farmers' income as governed by extension agents. The goal of this article is to supply new knowledge and policy that will improve the farmers' productivity and provide new information to amend the service of extension agents in the country.

## MATERIALS AND METHODS

The location of this survey study is Barangay Poblacion, Albuera, Leyte, Philippines which is considered one of the large rice land areas in Albuera, Leyte. This site has a lot of paddy farmers that are reached out by extension agents. In that case, most of the farmers in the area are guided in regard to farming technologies and innovations. The survey only considered the small-scale farmers working with an average of 2 hectares of rice fields. Map 1 below displays the location of the survey study.


Map 1. Location of Albuera, Leyte, Philippines
Source: [13].

The research design applied to this study is a descriptive-correlational study where it applies some descriptive statistics to summarize the gathered information and constructs an econometric model to make an inference. In determining the number of participants, a sampling technique called simple random sampling was employed. As for the sample size, Slovin's formula was used as follows:

$$n = \frac{N}{1 + Ne^2} \qquad ...................................(1)$$

where:

n – refers to the sample size, $N$ – refers to the population size (all farmers that are reached out by an extension agent); and $e$ – refers to the margin of error, the margin of error in this study is 5%. The sampling frame of all farmers was provided by the Municipal Agriculture Office (MAO) of Albuere, Leyte. Hence, this study considered 73 farmers in the Barangay to represent as participants of this study. Indeed, an ethical procedure was observed in the survey, a letter of permission was sent to the head of MAO, and participants were informed that the survey was voluntary and their response is highly confidential and solely used for this article only.

Concerning the survey questionnaire, it is developed structured type that was utilized to gather relevant information for this article. The said questionnaire is a guide for the interviewer for a face-to-face interview. The interview was done using the dialect of farmers in order for them to understand clearly and answer the questions accurately. The questionnaire contains the socio-demographic profile, the farmers' perception of the extension agents' role, and the farmers' monthly income in rice farming alone. For socio-demographic, captures the following: age of farmers (in years), sex of farmers (0-female, 1-male), education of farmers (0 - non-college graduate, 1 - college graduate), farm owner (0 - No, 1 - Yes). Additionally, the farmers must rate (perception score from 1 to 5) the following: (1) Educator, (2) Mediator, (3) Organizer, (4) Facilitator, (5) Solution giver, and (6) Enabler. Table 1 presents the guide for farmers' response to extension agents' roles.

Table 1. Scoring guidelines for extension agents' role

| Interval perception scores | Verbal rating |
|---|---|
| 1.00 – 1.80 | Very unsatisfied |
| 1.81 – 2.60 | unsatisfied |
| 2.61 – 3.40 | Undecided |
| 3.41 – 4.20 | Satisfied |
| 4.21 – 5.00 | Very Satisfied |

Source: Authors' own guidelines (2022).

Furthermore, economic profit (₱) in rice farming (one cropping season) was calculated as total revenue (₱) less total expense or cost (₱). Since one cropping season in rice farming will take place for about 4 months [27], then monthly income (₱) in rice farming is calculated as economic profit(₱) divided by 4. After the survey, the data gathered has undergone a clearing or removal of outliers (extreme response). In the data management, mean (M), standard deviation (SD), minimum (min), and maximum (max) value was computed as descriptive measures. Furthermore, an econometric regression model in the form of ordinary least squares (OLS)was constructed to acquire the significant factors of farmers' monthly income (dependent variable). The independent variables are the socio-demographic and farmers' perception to the extension agents' role. Thus, the empirical econometric model has the following form:

$$I_i = \partial_0 + \partial_1 age_i + \partial_2 male_i + \partial_3 educ_i + \partial_4 own_i + \partial_5 educator_i + \partial_6 mediator_i + \partial_7 organizer_i + \partial_8 facilatator_i + \partial_9 solution_i + \partial_{10} enabler_i + \epsilon_i \quad ............(2)$$

where:
$I_i$ refers to the farmers' monthly income (₱), $age_i$ refers to the farmers' age in years, $male_i$ refers to a dummy variable that captures male farmer, $educ_i$refers to a dummy variable that captures a farmer who is a college graduate, $educator_i$ refers to the farmers' perception score of an extension agent as an educator (Score of 1 to 5), $mediator_i$ refers to the farmers' perception score of an extension agent as a mediator (Score of 1 to 5), $organizer_i$ refers to the farmers' perception score of an extension agent as an organizer (Score of 1 to 5), $facilatator_i$ refers to the farmers' perception score of an extension agent as a facilitator (Score of 1 to 5), $solution_i$ refers to the farmers' perception score of an extension agent as a solution giver (Score of 1 to 5), $enabler_i$ refers to the farmers' perception score of an extension agent as an enabler (Score of 1 to 5), $\partial_t \forall t \in \{0, 1, \ldots, 10\}$refers to the parameters to be approximated and $\epsilon_i$ refers to the remaining random error in the model (1). STATA version 14 was used to obtain accurate calculations and diagnostic tests were also done to assure the validity of the model (1).

## RESULTS AND DISCUSSIONS

### Socio-demographic profile

In Table 2, it is revealed that the average age of rice farmers in Barangay Poblacion, Albuera, Leyte is close to 58 years old. The youngest is 36 and the oldest is 79 years old. This result is parallel to the findings of Casinillo and Seriño [7] that most rice farmers nowadays are mostly adults or older people since their young ones are sent to schooling to find decent work after. About 63% of these rice farmers are male and only 37% are female. It is worth noting that rice farming is a masculine job, hence, most are males who can manage this work well [4]. About 41% of these farmers own their rice fields and 59% are just tenant who cultivates the paddy farm with a rental fee to the landowner. This scenario is very common in the rural areas of Leyte, Philippines where most of the farmers are tenants rather than the owner of rice fields [4], [7]. Most (89%) of these farmers did not graduate with a bachelor's degree, hence, their knowledge used in farming is coming from their experiences. In that case, farmers of this type need guidance from extension agents [24], [14]. Moreover, the rice farmers' monthly income is about 5,047.95 pesos. The minimum is 3,000 and the maximum is 15,000 pesos. The rice farmers with high income are the one who applied innovative technologies in agriculture that improves their production [25]. In that case, to improve economic profitability in rice farming, farmers must be guided by an extension agent concerning their problems and constraint that need to be addressed [11], [19]. Hence, the right information in farming that is imparted by extension agents will lead to efficient productivity as well as the well-being of farmers.

Table 2. Farmers' profile

| Variables | M ± SD | min | max |
|---|---|---|---|
| Age of farmers | 57.79 ± 9.49 | 36 | 79 |
| Male[a] | 0.63 ± 0.49 | 0 | 1 |
| Owner[a] | 0.41 ± 0.49 | 0 | 1 |
| Education[a] | 0.11 ± 0.31 | 0 | 1 |
| Monthly income[b] | 5,047.95 ± 2,208.20 | 3,000 | 15,000 |

Note: a - dummy variable; b - Philippine Peso (₱);
Source: Own calculation based on data gathered (2022).

### Extension Agents' Role

As seen in Table 3, farmers are satisfied with the extension agent as an "educator" (M=3.67, SD=0.75). This implies that the extension agent has imparted some useful knowledge to farmers concerning educational technologies in rice production and other post-harvest activities. This transfer of knowledge is done through training or seminars in the form of farmer field school (FFS) that influences their attitude and practices in farming [25]. In the first place, the role of the extension agent is to help farmers through educational means to improve their way of living and improve their economic income [16]. Secondly, the farmers are undecided about their perception of the extension agent as a "mediator"(M=2.85, SD=0.89). This implies that farmers cannot somehow see extension agents as an intermediary in developing communication systems with local organizations in their place. In other words, farmers are not satisfied with linking or coordinating services and promoting collaborationism with rural development stakeholders. According to Rivera [26], it is a responsibility of an extension agent to serve as a liaison between experts in agricultural sciences and local farmers.Farmers' perception towards the extension agent as an "organizer" is approximately satisfied (M=3.74, SD=0.88). In this case, extension agent is doing their duties as an arranger of events and other opportunities for economic development like cooperatives and training. It is stated in the book article of McDonnel et al. [18] that organizing cooperatives is very helpful for small-scale farmers to take advantage of economic and financial opportunities that might improve their entrepreneurial practices. Also, the extension agent as a "facilitator" is rated as satisfied (M=3.41, SD=0.88) by farmers. This indicates that an extension agent has facilitated the farmers in addressing the constraints and other problems in agricultural production and development. Daum and Birner [11], stated that farmers need extension agent that facilitates the needs in financial aspects concerning agricultural mechanization to improve efficiency in farming. However, farmers are undecided to their rating to an extension agent as "solution giver" (M=3.37, SD=0.83) and "enabler" (M=2.63, SD=0.91). This implies that an extension agent cannot always solve the existing problems of a farmer concerning all aspects of agriculture-related. In addition, an extension agent does not always made his clients (farmers) capable of coping with the risks scenario to focus on their main goal which is economic profitability. According to Nakano et al. [19], it would have been effective if farmers are provided with a farmer-to-farmer extension program governed by extension agents to solve their problems in terms of technologies, financial aspects, output distribution (supply chain), and marketing, among others. Moreover, the farmers' overall perception of the extension agent is undecided (M=2.63, SD=0.91). This implies that the extension agent in their place must be strengthened and must be trained well to effectively function in their respective role. Farooq et al. [12], stated that extension agents must undergo an agricultural training course to disseminate innovative agriculture technologies and to construct policy suggestions for sustainable development.

Table 3. Farmers' perception of extension agents' role

| Variables | M ± SD | Description[d] |
|---|---|---|
| Educator[c] | 3.67 ± 0.75 | Satisfied |
| Mediator[c] | 2.85 ± 0.89 | Undecided |
| Organizer[c] | 3.74 ± 0.88 | Satisfied |
| Facilitator[c] | 3.41 ± 0.88 | Satisfied |
| Solution giver[c] | 3.37 ± 0.83 | Undecided |
| Enabler[c] | 2.63 ± 0.91 | Undecided |
| **Over-all** | 3.28 ± 0.85 | Undecided |

Note: c - Score of 1 to 5; d - See Table 1.
Source: Own calculation based on data gathered (2022).

## Econometric analysis

Table 4depicts the different diagnostic tests for the OLS model to guarantee the validity of making an inference to the results. Firstly, the Breusch-Pagan test found that the OLS model is heteroscedastic ($p$-value<0.001). This means that the variances in the model are not constant and it needs to be corrected [15]. Hence, the model was rectified using the robust command in the STATA to arrive at homoscedasticity concerning the variances [6]. With the aid of the Ramsey RESET test, it is revealed that the model has no omitted variable bias and implies that the variables included in the model were appropriate and relevant as predictors ($p$-value=0.137) [10]. Moreover, the variance inflation factor (VIF) revealed that the econometric model does not suffer from multicollinearity problems which implies that no association was found in the pairwise correlation of predictors (VIF=1.51). This means that without the multicollinearity problem, no factor can undermine the statistical significance of a predictor [1]. Furthermore, by the Shapiro-Wilk test, it is revealed that the model has normal residuals, that is, normally distributed. This implies that the model's assumption is valid and will lead to a reliable inference and predictions of the results.

Table 4. Diagnostic tests

| Test Statistic | | $p$-value | Interpretation |
|---|---|---|---|
| Breusch-Pagan test | $\chi^2$=8.41 | 0.004 | Heteroscedasticity |
| Ramsey RESET test | $F$=1.92 | 0.137 | No omitted variables bias |
| Variance inflation factor (VIF) | VIF=1.51 | - | No Multicollinearity |
| Shapiro-Wilk test | $Z$=-1.190 | 0.883 | Residuals are normal |

Source: Own calculation based on data gathered (2022).

Table 5depicts that the created econometric model is significant ($F_c$=3.71, p-value<0.001) at a 1% $\alpha$ level. In fact, the coefficient of determination (goodness of fit, $R^2$=0.435) shows that the model has a better fit. This means that there are causal factors (demographic profile and extension agents' role) influencing the monthly income of rice farmers. However, the model reveals that the following variables does not influence the monthly income of farmers at 10% level (at most): (1) age of farmers (p-value=0.992), (2) sex of farmers (p-value=0.987), (3) perception of farmers to extension agent as "educator" (p-value=0.882); (4) perception of farmers to extension agent as "mediator" (p-value=0.640); (5) perception of farmers to extension agent as "solution giver" (p-value=0.570); and (6) perception of farmers to extension agent as "enabler" (p-value=0.789).
On the other hand, the model depicts that the following predictors are significant at a 10% $\alpha$ level (at most): (i) farmers own their rice

fields (p-value=0.003); (ii) educational attainment of farmers (p-value=0.001); (iii) perception of farmers to extension agent as “organizer” (p-value=0.100); and (iv) erception of farmers to extension agent as “facilitator” (p-value=0.080).

Table 5. An econometric model for farmers’ monthly income and its causal factors.

| Causal Factors of Monthly Income[b] | Econometric (OLS) Model | | |
|---|---|---|---|
| | *Coefficient* | *Std. Error* | *p-value* |
| ***Constant*** | 3.61756** | 0.1242 | <0.001 |
| Age of farmers | -0.00002[ns] | 0.0018 | 0.992 |
| Male[a] | 0.00059[ns] | 0.0363 | 0.987 |
| Owner[a] | 0.10590** | 0.0342 | 0.003 |
| Education[a] | 0.24968** | 0.0684 | 0.001 |
| Educator[c] | -0.00445[ns] | 0.0298 | 0.882 |
| Mediator[c] | -0.01077[ns] | 0.0229 | 0.640 |
| Organizer[c] | 0.03423* | 0.0217 | 0.100 |
| Facilitator[c] | -0.0360* | 0.0203 | 0.080 |
| Solution giver[c] | 0.0114[ns] | 0.0199 | 0.570 |
| Enabler[c] | -0.0038[ns] | 0.0144 | 0.789 |
| ***Observation*** | 73 | | |
| ***F-computed*** | 3.71 | | |
| ***$p$-value*** | <0.001 | | |
| ***Coefficient of determination*** $(R^2)$ | 0.435 | | |

Note: a - dummy variable; b - Philippine Peso (₱); c - Score of 1 to 5; ns- not significant; * - significant at 10%$\alpha$ level; ** - highly significant at 1%$\alpha$ level.
Source: Own calculation based on data gathered (2022).

It is worth noting that if the farmer owns the paddy farm, then the farmer does not pay any more a rental fee for using the farm. In that case, the farmer only spends on agricultural inputs and labor expenses which indicates that owning a farm is a significant advantage as opposed to a tenant farmer. This result is consistent with the study of Casinillo and Seriño [7] which also found that farmers who own the farm are more likely happy or satisfied as a farmer. This is for the reason that the expense of rental fee for land is out of the equation for their profit computation.

Secondly, if the farmer is knowledgeable or educated they have a good attitude and practices in production. In fact, educated farmers are more capable of doing good farm management which will lead to better farming behavior which increases their profitability [25]. Moreover, farmers' education is a big help in understanding and finding the solution to the different problems in production. It also enhances their farm productivity by adopting the latest modern agricultural technologies [22].

Extension agent as "organizer" of farming and training activities has an impact on the farmers' monthly income. This means that a farmer who involves in the training gain additional knowledge on how to improve his farming skills. In addition, a farmer who is guided and supervised by an extension agent has an advantage because they are introduced to new innovative technologies that help to produce more rice yield. In fact, better interaction with a farmer and extension agent concerning with right information may help small-scale farmers in the acquisition of developing the living condition in farming [18], [9]. In that case, acquiring new knowledge in the farming system will enhance their ability to adopt new technologies which improve their rice production process as opposed to traditional ones. Moreover, organizing a farmers association will lead to a discussion of addressing the needs of farmers and problems encountered in farming. On the face of it, an extension agent can give a piece of advice and suggest a policy so that the government will support the farmers' concerns [16], [31].

On the contrary, the result of the model revealed that the extension agent as a facilitator has negatively impacted the rice farmers' income. This implies that the extension agent has not properly facilitated the farmer to their main goal which is economic profitability. This result is not consistent with the existing studies in the literature that extension agent is a great help to marginal farmers in rural areas [18], [19], [12], [9]. It is worth noting that an extension agent as a facilitator is one who educates and facilitates a group of farmers to work toward a common goal or objectives. Extension agent has the target of imparting to marginal farmers the quality of skill competence, and teamwork and facilitating them to increase productivity despite problems in agriculture. Likewise, an extension agent has the desire that a farmer must have a better understanding of climate science and its nature in agricultural management and practices [29].

## CONCLUSIONS

Results revealed that the farmers' monthly income is below the poverty threshold in the country. This indicates that rice farmers in Albuera, Leyte must be guided and assisted by the Philippine government to somehow progress their economic income and well-being. On average, rice farmers' perception score towards extension agents can be interpreted as "undecided" concerning satisfaction. This can be concluded that they are not satisfied with the function of extension agents as an aid in increasing their productivity in rice farming. Conclusively, the government must support the farmers concerning their agricultural needs like machinery and equipment for farming. This can help farmers lessen their expenses from rice field cultivation to harvesting. Additionally, the agricultural sector and local government unit must support the farmers by providing them with a trained extension agent (well-educated) that will educate the farmers in adopting new technologies and innovations. These extension agents will organize farmers' associations that will conduct meetings or discussions regarding the farmers' constraints in production and provide a solution to their problems. The local government unit also must build cooperatives with the help of extension agents to address the farmers' needs in agricultural expenses and savings. In this regard, farmers may increase their productivity as well as their monthly income. The study suggests that a similar survey should be conducted with a large sample in other rural places of Leyte, Philippines to enrich the findings of this current article.

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# EVALUATION OF RURAL TOURISM IN TERMS OF RURAL DEVELOPMENT WITH THE COVID-19 PANDEMIC

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***Abstract***

*Rural tourism provides an environment where rural people meet different cultures, prevents immigration to already crowded city centers, becomes an element of rural development, creates income diversity and protects the environment as well as natural, cultural and historical aspects of regions. The aim of this study is to examine effects of COVID-19 pandemic on rural tourism-potential and rural planning using Cizre District, Turkey, which incorporates distinct geographical, cultural and historical elements in a rural environment. Data were collected using primary and secondary sources in the region. SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was used to analyze data which shows an increase in migration to rural causing environmental pollution. Positive effects include increase in commerce and housing demand strengthening the economy following normalization. Findings should help to review and improve sustainable planning and policy strategies supporting new economical environment in rural. The development strategies need to focus on rural and urban being partners rather than rivals.*

***Key words*****:** *rural, tourism, covid-19, development, sustainability*

## INTRODUCTION

Investigating relationship between the environment and cultural heritage in terms of tourism has been increasingly attracting researcher's interests [34, 20, 21, 14]. At the same time, tourists have been demanding more sophisticated and economical options from the tourism sector in general. As the sector tries to become more competitive to meet the demand, traditional 3S (sea, sand, sun) concepts appear to be insufficient, and efforts to develop new concepts are required. This results in increasing efforts by the tourism companies to meet demand, and new tourism concepts such as rural tourism, ecotourism, nature tourism, health tourism, geotourism [15] and faith tourism have already emerged [30]. These emerging concepts take their strength from incorporation of elements of a more peaceful, calm and natural environment. Even with the emerging versatile concepts, tourists seek additional specific areas of enjoyment that include local authenticity and genuine aspects to complement their 3S visits. These specific areas or components are expected to enrich their visit and may include gastronomy, folklore, and faith aspects that are unique and different from those found in common destinations. Such areas with genuine, unique, authentic aspects became more important for tourists and locals as well; because economical activities around tourism help locals to prosper, and interactions with people of various backgrounds enrich their knowledge, appreciation, and acceptance of cultures that are usually different than theirs. These areas offering such opportunities are generally located outside (but not necessarily far from) areas of traditional 3S destinations, mainly in rural areas, where out migration, youth/women unemployment, and sub-standard infrastructures are generally main concerns for local population [28, 31]. Although all types of tourism are supposed to be sustainable, the 3S model has lost its sustainability in the current situation. This situation can make rural tourism more popular. More recently, as a result of the Covid-19 pandemic (SARS-CoV-2: violent acute respiratory syndrome coronavirus-2) event which has emerged since December 2019 and currently continues affecting the world's population, tourists and general public alike have started to be interested in calmer natural places for their tourism activities and divert their attention to places away from regularly crowded places that pose high risk from the virus. The size of population affected from the pandemic keeps accumulating. The total number of Covid cases in the world is 526 million and the number of deaths is 6.28 million in total, until May 23, 2022 [37]. In those days the large urban population feel helpless with so many compulsory (and necessary) restrictions in their lives. It can be anticipated that the interest in local and rural places will grow further due to recently emerging factors such as the pandemic, environmental pollution and the climate change. This change and transformation can offer new opportunities in the planning of rural areas.

Rural tourism contributes to rural development as well. It could generate a significant source of income for those living in small villages or settlements with very small income, insufficient to sustain their livelihood from agricultural activities. For those people income would have been further reduced as a result of the current pandemic.

The pandemic adversely affected many small-scale fresh fruit and vegetable growers, restaurants, and grocers. For example, community markets were allowed to operate within restricted hours and restriction were put in place for people's movement affecting personnel operating these markets. The only way of accessing fresh food during pandemic is to provide conditions for the small producers, and farmers in villages or cities, to market their products in local markets at an equitable price [26, 5].

The South Eastern Turkey is a mostly rural region of Turkey that has unique characteristic features. Its history goes back to 4000BC, it has a site believed to be Noah's Tomb, and it has a deep and rich culture with traditional and modern elements; including aspects of gastronomy, languages, religion, and hand crafts. The region also has been gaining more attention with the discovery of nearby Göbekli Tepe [40]; but many unique localities, like the Cizre District, in the neighbourhood of Göbekli Tepe are yet to be discovered by the general tourist population. The Cizre District (Map 1) is a settlement with low socio-economic characteristics, under-developed in terms of infrastructure and industry, and has a multicultural society. It comes forefront within South-Eastern Turkey with its authentic culture, encompassing unique elements such as geographical features (e.g., Tigris River and tributaries), history (sites from pre-history to present), gastronomy (various ethnic foods), folklore and faith (e.g., cultural life affected from various religions). Together, these and a 12-month favourable climate (summers sunny and hot, winters mild and rainy) should make the region a favourable destination for rural tourism.

This study was aimed to explore various characteristic of the Cizre district and assess their pre-, current, and post-pandemic potential for rural tourism and economy of district. SWOT analysis technique is used in the assessment. SWOT (Strengths, Weaknesses, Opportunities, and Threats) is a tool widely used by managers and experts in strategic planning [46]. The study uses Cizre as a case study with ideas and approaches being applicable to many areas of the world in local or a more regional scale.


Map 1. Location-Cizre District, Turkey
Source: created by the author, 2021.

## Rural Tourism and local development within Pandemic

### *Rural Tourism*

Rural tourism can be defined as visits to rural areas where travellers can have authentic, unique experiences by interacting with local people and their lifestyles [28, 30, 31]. It is a type of tourism that is both intertwined with rural areas and based on natural resources; and can be easily integrated with other types of tourism [43]. Visits to rural areas are for a short time, and can be done at various times of the year and generally in many seasons [8]; allowing rural tourism activities to be done alone or as complementary or extension to the 3S (Sun Sea and Sand) type activities. Generally, rural tourism is perceived as a form of tourism that exhibits rural life, art, culture and nature of rural areas [24]. It encompasses all aspects of touristic activities taking place outside the urban areas.

Participants in rural tourism are usually middle-aged people, middle-income group of highly educated and professionals. In addition, due to the increasing prevalence of various sporting activities in rural areas, it also makes young people interested in rural tourism even if not directly. There are even pedagogical farms where only children are accepted in some European countries [43].

Specifically rural tourism have the following characteristics [43, 16, 12]:

● can be done in all seasons, perceived to be healthy with fresh and clean environment
● is a balance element in the geographical distribution of tourism
● can be integrated into many types of tourism
● recreational activities in rural tourism are very diverse and unique
● the tourist profile of rural tourism is different
● contributes to the protection of the natural environment and cultural heritage
● serves the concept of sustainable tourism
● is an important tool for the promotion of a country
● is a type of tourism based on environment, people and natural life
● authenticity stands out
● is integrated and developed with local people
● preserves the diversity of agricultural and animal products intertwined with village life
● economic, environmental, social and cultural goals are pursued in rural tourism
● envisages improving employment opportunities for the local population

Rural tourism is seen as an important factor in diversifying the rural economy [31] creating a new perspective for the people living in rural areas, balancing the income level and preventing migration in rural areas, protecting nature and providing regional development. Successful rural tourism practices allow local people engaged in agriculture to earn additional income, increase their wealth and share their cultural wealth [3] and rural tourism will only be able to meet expectations and benefit the local population only if properly integrated with the local economy [11, 31] and reveals the spirit of unity and entrepreneurship [32].

Despite the broad scope of rural tourism with respect to touristic opportunities and practices, it has long been recognised that the fundamental attraction of the countryside as a tourist destination lies in what is often referred to as a sense of rurality [2, 13, 23, 27, 48, 29]. In other words, tourists are not only influenced by rural areas' physical characteristics and their inner qualities such as open-space, fresh air or peace and quiet; they are also influenced by what the countryside represents [29]. Rural areas are also seen as alternative settlement areas and facilities; such as entertainment facilities, leisure time activity centers, or as second homes. These developments are closely linked to redefinition of the rural identity. They reflect new traditions, new interpretations, encouragement of social demands, and a cultural interest in wider population to what is rural and local [9].

***COVID 19 and rural tourism***

COVID 19 hit the urban centers the most as compared to the rural areas; both because of the size of population and the proximity of population enabling the spread of the highly infectious disease. The United Nations Conference on Trade and Development (UNCTAD) recently reported 130 million people are being threatened with harsher poverty due to COVID 19. The study indicated that the pandemic hits poor the most. Among those groups being severely affected are migrants, women, or small establishments employing disadvantages people such as low income family members, and traditional tourism in general [44, 42].

The rural regions, specifically regions with harsh climate and rugged geography, are very vulnerable to many risks as well. A study by Ali et.al. (2020) [1] undertaken in rural and mountainous region of Pakistan showed that 78% of participants are in financial uncertainty, 64% experienced income reduction, 6% lost their jobs, and 25% of participants are afraid of losing their jobs. The researchers conclude that rural population engaged in rural tourism and agriculture have been adversely affected and their income reduced as a result of pandemic coupled with the change in climate [1]. However, relatively larger open space and scarce population in rural still allowed many recreational facilities and less chance of coming into contact a virus carrier especially if done in small groups. Rural houses, tents and caravans, rural motels, rural pensions and rented rooms, relatives and acquaintances, being the normal forms of accommodation for rural tourism participants, helped to decrease the contacts when compared to urban facilities. According to a survey conducted in Czechia by the Institute for Politics and Society in June 2020 [47], people want more rural activities (more second housing, cycling, hiking, natural monument visits, water sports and camping).All these elements indicate the rural tourism to be a more important income generating activity during (and after) the pandemic for the development of the rural areas and their natural habitats. It is stated in many studies that rural tourism attracts more attention after the pandemic [33, 38, 39]

***Development policies***

The conditions created with the current pandemic, explained in the previous sections call for a review of development policies with a view that integrates urban and rural jointly as a sustainable system. In connection with globalization, the pandemic created a general anti-urban feeling among the general population. It caused an increase in the existing polarization between pure and clean rural areas against dirty, dangerous, and crowded cities [10].An integrated system should show a clear interdependency of the regions and alleviate the negative sentiments. Thus, the development strategies need to focus on rural and urban being partners rather than rivals.

Development policies must be sustainability based and intend to increase economic activity of the region to increase employment, decrease poverty, rehabilitate the environment and improve the overall health of the population. The policies should be developed such that they can be implemented at suitable cost, help to increase income, and can be implemented rapidly and effectively [7].

The development policies should also consider that there could be certain negative effects; which may include environmental pollution and destruction of nature, increase in socio-cultural pressures, the formation of accommodation problems, foreign investors ‘taking over’ the region, excessive visitor traffic, excessive vehicle and traffic density, garbage, waste, and environmental pollution [18]. In order to minimize the negative impacts that may occur with rural tourism, it is of utmost importance that rural tourism activities are organized in a way that does not harm the environment and rural life.

In this respect, rural tourism can be a tool for the development of rural areas and for raising the economic level of the region. In this study, it is aimed to investigate the Cizre district of Turkey's relatively undeveloped Southeast Region for its potential of rural tourism.

## MATERIALS AND METHODS

The study area of Cizre District is located in the South-Eastern region of Turkey. Data were collected using primary and secondary sources in the region. The geographical, environmental, cultural, agricultural and economical, gastronomy, historical and religious aspects of the district were considered in the investigation.

SWOT analysis was used to reveal the rural tourism potential of Cizre district and to in versatile evaluate its contribution to the development of the region.

## RESULTS AND DISCUSSIONS

### Characteristics of the Cizre district contributing to its tourism potential

***Geography***

Cizre is located in the historically fertile South-Eastern Turkey with various geographical features that can attract tourists of all interest groups. The presence of the Göbekli Tepe archaeological site, recognized as the world's oldest temple and included the World Heritage List, adds to all. Discovered only recently it is an eye-opener for many reasons; specifically for its 12,000 years history, thus its importance in human history and development [40].Its importance for Cizre is that this popular tourist destination is only 323 km away from the Cizre District and Cizre is one of the beneficiary of extended visits to Göbekli Tepe, thus additional opportunity for Cizre to promote more local features of her own. Specific geographical features of Cizre includes unique nature and river landscapes, streams, mountains, historical and cultural values within the rural areas that have important resources for tourism. Hunting is possible, wildlife of the mountainous areas is rich with species such as partridge, rabbit and quail. The local cuisine and local handicrafts of Cizre district are rich enough to add the strength to the implementation of rural tourism. Also the villages of the district provide agricultural products and Tigris River and its tributaries allows rafting and nature walks along its shores.

***Culture***

Heritage, whether it be an object, monument, inherited skill or symbolic representation, must be considered as an identity marker and distinguishing feature of a social group. Heritage is often a subjective element because it is directly related to a collective social memory, "a combination of recollections recognized by a given group" [6].

Cultural and social identity of a given community is preserved in collective social memory through more or less ritualized circumstances. The common heritage appears as a ritual code. It is recognized as a unifying sign or remembered as a common setting in a designated area. Tourism permits participation in consumption and celebration of a series of local rites, including numerous events set up to show off heritage riches, allowing the tourist social and cultural integration in the local group by absorbing and reproducing cultural codes [9].

People have always known how to make up technical, socio-economic and symbolic solutions using heritage components. Heritage is therefore no longer considered solely as a link between past and present, but also as a reservoir of meaning necessary to understand the world: a resource in order to elaborate alterity. Dressing based on culture specific dressing is a component of cultural heritage.

Clothing & Ornaments in the Cizre District: Local clothing is called "şalşapik". In the past, fermani was worn. The old men wore baggy jackets, vests and helmets. Suits became more of the trend only after 1970s. Therefore it is still highly likely to observe people with colorful traditional clothing and ornaments while relaxing in common grounds of the general Cizre district. Literature/legend Memu Zin: Memu Zin is a poetic love story between Mem and Zin which is a legend in the region. There is also a book written by Kurdish writer Ahmed-i Hani in 1692 that is considered to be epopee of Kurdish literature. The book has been translated to many languages including Turkish, Farsi, Arabic, French, and Russian. Today, the presumed resting place of the Memu Zin is visited by locals and tourists alike. The story has become an oral legend as well; with even non-educated ones in the region recite it from memory [41].

***Agriculture and Economy***

Agriculture forms the basis of rural life to sustain. However unfavourable climate and poor soil conditions, specifically in rough geographical areas, may restrict the extent of the agriculture. In those conditions any rural tourism income may be the savour for local inhabitants. More favourable areas can offer additional organic and local varieties that can attract visitors' attention. In the Cizre District high temperatures and poor soil conditions are disadvantages for extensive traditional farming. Certain endemic flower varieties allow specially-flavoured honey production.

Trade and service sectors take the first place in business and working life in the Cizre district. This is followed by agriculture and animal husbandry sector [19]. The presence of rich lignite and asphalted deposits and the high potential of using solar energy is helpful for organic production. The low labor costs and favourable climate makes most of the district's agricultural areas suitable for greenhouse type cultivation [35]. Rural areas have various endemic plant species. There is little use of pesticides and synthetic fertilizers in the district. Many traditional handcrafts, such as Tinsmithing are well practiced in the Cizre district.

***Gastronomy***

Gastronomy is an essential component of enjoyment for the travellers. Eating during holidays is a fun activity and a fundamental part of rural tourism. Because it is culturally related, both the food and the act of preparing the food during rural tourism can be associated with a special social status and a special cultural system. Eating habits form the basis of a collective identity and therefore indicate the diversity [9].

Awareness about food is changing as well. The popularity of food with a country touch and natural products has been increasing. Black bread or bread baked in brick ovens, fresh farm products are cooked and prepared right at the farm buffets and meats are from the village animals at a reasonable price are a few examples that are usually found in high-priced restaurants if in non-rural environments. At one side, the mistrust in industrial food products is growing due to real and/or imagined side effects of chemicals and colouring additives. On the other side, marketing professionals sometimes use terms generously which makes the consumers to believe that they are getting fresh farm products, which in fact are mass produced in industrial facilities [9].

Visitor are usually curious about local food. Cizre has its own special tastes that are displayed in various dishes. Cizre food culture is among the richest in the region with its roots dating back to Babylonian and Gudi Empires. According to Adullah Yasin's book called "Botan Food Culture", there are 357 food and beverage types including 17 unique and famous dishes, 48 meat/breads, 112 vegetable dishes, 29 soups, 47 desserts, 48 pies, wraps and breakfast, 16 salads and garnish, 12 pickles, 28 bread types unique to Cizre District. A typical "Cizre Menu" may include one or more of the following genuine Cizre dishes: Kuliçe, Katkidifsi, Fıreydin, Mahmılatık, Sorbidev, Kutlık, Mumbardolması, Perdepilav, Şipşıpe, Meyre (Mehir), and Brinzer.

***History***

Cizre has many historical sites, passed on from different centuries of her past that worth visiting. One of the most outstanding and visible of these is the ship-shaped, 360-roomcitadel with walls wrapping the city. Other historical sites include Bırca Belek built attached to the citadel in 1596 on shores of the Tigres River, various Medreses (old high school/university) dating 15 century, and a military compound from late Ottoman Era [41].

There are also older sites dating back to 4000BC. Among them: The **Finik Site** which has a palace, dungeon, cistern, carved rock reliefs, and many settlement areas and many cave houses; **Kasrik Site** on 6km north of Cizre; **Şah Site** on northwest of Cizre in the Çağlayan Village that has scattered historical localities of Düşe, Çeko, Hırabe, Kayser, and Hırd castle; **Babil Site** on South-West of Cizre in the Kebele Village where a statue belonging to Assyrian Kings was found in 1992 and currently on display in Ankara Anatolian Civilization Museum; and **Bazebde Site** on 2km east of Cizre on shores of the Tigris River with ruins of a settlement and a bridge from early historical era [41].

***Religious sites***

Cizre has many mosques, churches, and other religious sites and structures dating back many centuries. One of them, the Cizre Ulu Cami dating back to the seventh century AD has a peculiar iron gate with silver motifs and copper figures. One such figure, known as the Dragons of Cizre is an outstanding art work that has international reputation. The Dragons of Cizre were rebuilt by Al-Cezeri in XII. Century using scraping technique. They were made of bronze as knockers of the inner door of the Great Mosque of Cizre. Two sphinx dragons, winged creatures have almond-shaped eyes, pointed ears, and displayed to bite each other's wings. Two dragoons are to represent two rivers in the Cizre area: One to represent Tigris River and the other the Euphrates River; with the lion's head in the middle to represent the people of Cizre, and eagles in the lower section to symbolize the military power. One of these door knocker from the gate of the Great Mosque of Cizre was smuggled to Denmark in 1969 while the other is on display at the İstanbul Turkish Islamic Works Museum [17]. Other outstanding religious sites include a site believed to be Noah's resting place (Noah's Mosque), Mecdiyye, Mushafireş, Mir Abdal (1437), Ş. Said and Meydan Mosques.

The Noah's Mosque containing Prophet Noah's tumb, named after Noah's of the great flood times, is located at the top of the Dagkapi neighbourhood, at a point where the Tigris River's floods could hardly reach. The tomb is on the lower basement. It was restored by the Noah Nebih Mosque Building and Living Society (NNMBL) and Şirnak Governorship [41].

**SWOT analysis**

One of the most effective way of presenting the current status and objectives of a sector, an activity, or an enterprise is to perform SWOT analysis by persons who are knowledgeable about it [4]. SWOT Analysis is a method used to identify the strengths and weaknesses of an industry, an activity and an enterprise and to identify the opportunity-threats arising from the external environment. Therefore, it is necessary to reveal the strengths, weaknesses, opportunities and threats in terms of rural tourism and to make plans and programs accordingly [36].

The following isa SWOT analysis of rural tourism potential of Cizre District in terms of its strengths, weaknesses, opportunities and threats presented in Tables 1 to 4 respectively.

***Strengths*** are presented in Table 1.

Table 1. The identified strengths of Cizre in terms of rural tourism

| Items/Characteristics | Pre-Covid19 (Base case) | Post-Covid19 (Potential condition once Covid19 is over) |
|---|---|---|
| Availability of an unspoiled nature, clean environment, perceived healthy living and long life expectancy | ✓ | ✓ |
| Hospitality of the people | ✓ | Hesitancy in face to face communication due to the Pandemic experiences |
| Richness of local food variety, the presence of crafts and traditional motifs (birth, death, wedding costumes) and the importance practiced customs and traditions | ✓ | ✓ |
| Easy access to the Tigris banks, fishing in the Tigris river Tigris River being suitable for water sports | ✓ | ✓ |
| Availability of river transportation between Iraq and Anatolia | ✓ | Increases in the post-pandemic period |
| Providing land transportation link to Şırnak, Hakkari and Siirt provinces | ✓ | Increases in the post-pandemic period |
| Favourable climate to rural tourism throughout the year; tourism can be done 12 months a year in terms of climate | ✓ | ✓ |
| Having a rich food culture; the richness of local food variety, the continuity of local clothing, the presence of crafts and traditional motifs (birth, death, wedding, etc.) and special customs and traditions | ✓ | ✓ |
| Organizing various festivals, and shows and increasing the number of activities | ✓ | Weakens for some time after the Pandemic |
| Being close to a natural area which has important attraction for endemic species | ✓ | Getting stronger due to pandemic |
| Having a lively commercial life and being located centrally in the region, closer to the city center than other districts | ✓ | Increased commercial life, increased housing demand, increasing prices |
| Opportunity to settle in rural, low-cost housing | ✓ | Increasing potential |
| Providing opportunities for many ecotourism and/or rural tourism activities due to the moderate nature of its people | ✓ | Increasing potential |
| Being located very close to Kasrik Pass and Habur border crossing | ✓ | Increased due to incoming population |
| Having mountains (Gabar and Cudi) suitable for hunting, trekking and other sports | ✓ | Increased due to incoming population |
| Employment | ✓ | Increased due to increased activities and economy |

Source: created by the author, 2021.

***Weaknesses*** are shown in Table 2.

Table 2. The weaknesses of Cizre in terms of rural tourism

| Items/Characteristics | Pre-Covid19 (Base case) | Post-Covid19 (Potential condition once Covid19 is over) |
|---|---|---|
| Inadequate marketing of Cizre in terms of culture and tourism | ✓ | Potentially strengthens as in-coming migration increases. |
| Lack of knowledge about the importance of preserving the historical and natural beauties among the local people and the lack of awareness of rural tourism | ✓ | Potentially strengthens as the locals see economic benefit for themselves and interest increases |
| Indifference of local governments to benefits of tourism | ✓ | Potential cooperation with the experience of the pandemic |
| Inadequate shopping centers and entertainment venues in the district | ✓ | Potentially improvement |
| Lack of entrepreneurial culture in terms of rural tourism | ✓ | Potential improvement |
| Insufficient touristic tours and promotion in terms of rural tourism | ✓ | Potential improvement |
| Lack of rural planning and financial problems | ✓ | |
| Lack of promotion of the Tigris River for tourism | ✓ | Potential improvement |

Source: created by the author, 2021

***Opportunities*** are presented in Table 3.

Table 3. The opportunities of Cizre in terms of rural tourism

| Items/Characteristics | Pre-Covid19 (Base case) | Post-Covid19 (Potential condition once Covid19 is over) |
|---|---|---|
| A Vocational School located in Cizre district of Şırnak University | ✓ | Increasing enrolment, increase of young and active population. |
| Increasing migration to the district and increasing population | ✓ | Further strengthened. (increased population; especially with the return of old residents) |
| Increased housing | ✓ | Strengthened. |
| Presence of an airport in the district | ✓ | Further strengthened. Potential increase of air travellers |
| Support by the Dicle Development Agency | ✓ | Further strengthened |
| City hospital to be built in the district | - | ✓ |
| Having rich lignite and asphalt deposits and the possibility of utilizing solar energy | ✓ | Increases |
| Favourable conditions for greenhouse cultivation in most of the district's agricultural areas | ✓ | Increases |
| Establishment of Cizre Hydro Electric Dam and Power generator | ✓ | Strengthens (More energy would be needed for new activities) |
| Being suitable for cattle feed and cattle husbandry | ✓ | Strengthens. (Returning population engage in agricultural) |

Source: created by the author, 2021.

***Threats*** are reflected in Table 4.

Table 4. The threats of Cizre in terms of rural tourism

| Items/Characteristics | Pre-Covid19 (Base case) | Post-Covid19 (Potential condition once Covid19 is over) |
|---|---|---|
| Cultural pressure - risk of corruption, contamination and erosion of regional cultural values | - | Increases |
| Terrorism incidents in the district, political and economic instability | ✓ | Neutral or decreases |
| Limited job opportunities in the district and the decrease in the young population | ✓ | Increases. High potential to be removed as a threat and becomes an opportunity. |
| Excessive visitor traffic | ✓ | Increases |
| Damage to natural beauty due to intense interest | - | Increases |
| Pollution of Tigris River | - | Increases |
| Environmental pollution: Garbage, waste | - | Increases |
| Danger to wildlife: partridge, wild goat, etc. due to over-hunting and danger of extinction | - | Neutral |

Source: created by the author, 2021

Covid-19 changed the global environment for all sectors; including tourism. As pointed out by Higgins-Desbiolles (2020) [25], the pandemic provides an opportunity to “rethink and reorganise the tourism sector towards sustainable development”. There are several factors to be considered in this desire to reorganize such as the increase of crowds, both in rural and around the neighbourhoods in the urban centers that creates negative emotional responses towards tourism, and that proximity to crowded neighbourhoods resulting an elevated stress levels [22]. This is in agreement with the negative reaction towards crowds in rural areas and shows itself among weaknesses for rural area development in this study. Thus, it will be prudent to state that conditions created with the current pandemic supports for a call for a review of development policies with a view which integrates urban and rural jointly as a sustainable system. Rural tourism stands out as an important component of this new rethinking and reorganization. Rural tourism provides an environment where rural people meet different cultures, prevents immigration to already crowded city centers, becomes an element of rural development, creates income diversity and protects the environment as well as natural, cultural and historical aspects of regions. The success of rural tourism in fulfilling these elements would reflect directly on countries abilities to reduce growing financial burden on them caused by Covid-19 pandemic. The subject of this study, the Cizre Disrict, has potentials in geographical, cultural, agricultural, economical, historical and religious dimensions that affect overall outcome of touristic activities. Each of these areas are being affected by the pandemic. However, rural tourism offers an opportunity for the development of the region. The region is generally a poor rural area. Rural tourism can be a source of income for the poor people living in the region and negatively affected by Covid. In a survey conducted by UNESCO it was shown that the effects of the crisis on World Heritage properties may continue in the months to come. According to the survey, "90% of countries with World Heritage properties had closed or partially closed them and respondents to this survey still reported an average figure of 71% closure of sites in February 2021 [45]. These findings also reflect a situation where the tourism need to rethink and reorganize and sites like Cizre with its multi-faceted touristic opportunities could gain importance in such a reorganized touristic scheme. This study shows that alongside with an increase in commerce and housing demand strengthening the economy following normalization, there could be negative effects of incorporating rural tourism in this system such as potential increase of pollution extending to rural. More research is needed to investigate integrated, comprehensive and sustainable tourism incorporating rural and urban based tourism with after-Covid data. Such investigations need to put more emphasis on monitoring the projected effects of events such as COVID-19 for a full-scale economic and social assessment of tourism. The case studies such as the one presented here provides valuable data for various aspects of benchmarking and monitoring. The situation may show similarities for other developing countries. Rural tourism in the Cizre region may show some changes after Covid. More cautious behaviours may occur in face-to-face relations in tourism after the pandemic.

If people make a habit of keeping their distance, it will damage the relations of hospitality in tourism (Hospitality of the people). Massive crowds and large-scale festivals that bring more people together will be less organized. Maybe this situation will make it more common to organize festivals with smaller communities. Escaping from the city centers will also be able to carry commercial relations to more rural areas. Houses around the city, which are close to the countryside, will be in greater demand. Activities and sportive activities in the countryside will be diversified. This interest will enable rural people to recognize the natural beauties of the region and rural tourism potential and increase local entrepreneurship. Young and active population will be able to stay in the countryside instead of migrating to the city, and reduce unemployment by turning to economic entrepreneurship. On the other hand, better food demand can be a new application for the people of the region who can develop organic agriculture. With rural tourism, the service sector (restaurant, accommodation, etc.) will be strengthened in the region. Besides all these, there may undoubtedly be a terrorist risk and security problem in the region. On the other hand, the interest of people may lead to the pollution of the region, and the culture may be eroded.

## CONCLUSIONS

The Corona virus (COVID-19) pandemic and global recession caused by the pandemic is the most serious crises since the end of World War II. Most of countries in the world had a ready imported SARS-CoV-2 (violent acute respiratory syndrome coronavirus-2) disease and now trying to cope with its economic and and societal effects. This study shows that although the tourism activities and its overall economy slowed during Covid 19 in general, the rural tourism remains lesser affected or potentially beneficiary due to scarce population and open natural space of rural.

A pre-pandemic threat for rural development areas such as Cizre district was the limited job opportunities in the district and the decrease in the young population because of continues migration to urban centres. This out migration trend appears to reverse, thus becoming a potential strength for such regions after Pandemic. Similarly several aspects which were weakness in the SWOT analyses prior to pandemic shift to become opportunities due to changes brought about by the pandemic. These new conditions have potential to foster economic development sought after in rural areas. Sustainable rural tourism is also important for sustainable production, sustainable consumption and sustainable society. Sustainable rural tourism is very important to protect and develop rural settlements and thus strengthen their territorial integrity. As in the example of Cizre, the cultural, historical and natural wealth of the region can be turned into an advantage for rural development with rural tourism in the development of poor regions with limited income sources. The study also shows that there can be an increase in migration to rural causing environmental pollution. This sends a signal to planners and policy makers to review and improve sustainable planning and policy strategies in a comprehensive way to support the new economical environment in rural. The development strategies also need to focus on rural and urban being partners rather than rivals.

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# RESEARCH ON THE EVOLUTION OF THE GLOBAL BEEF MARKET IN THE PERIOD 2015-2020

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***Abstract***

*This research captures the changes that took place on the global beef market, for the period 2015-2020. The most representative indicators presented and analyzed are: total cattle herds worldwide; beef and veal production obtained worldwide; beef and veal consumption recorded worldwide; imports and exports recorded worldwide for beef meat. Beef contains a series of proteins, minerals, vitamins, fats and amino acids that recommend it for consumption, because it contributes to maintaining the population health. In 2020, Americas achieved 48.6% of the production of meat of cattle with the bone, fresh or chilled. The most significant consumption per inhabitant of beef and veal was highlighted in Argentina of 36.9 kilograms, in 2020. For the year 2029, the largest consumer of beef and veal is expected to remain also Argentina, with only 36.0 kilograms/capita. The basis of this research was, on the one hand, the statistical data taken from the FAOSTAT website, and on the other hand, the data retrieved from various specialized materials and sites.*

***Key words***: *beef, cattle herds, beef and veal consumption, beef and veal imports and exports*

## INTRODUCTION

According to studies, beef is that type of red meat recommended for consumption by nutritionists, because it contains numerous proteins, vitamins, minerals, amino acids, as well as "healthy" fats. All the above-mentioned elements have a key role in terms of ensuring an optimal health status [8, 11,13]. Nowadays, worldwide, cattle are bred for both meat and milk. Farmers all over the world who have as their first objective the raising of cattle for slaughter prefer meat breeds. These breeds have a great advantage, namely, they show a high yield in terms of growth. Another aspect that cannot be neglected in relation to cattle from meat breeds is represented by the lower care costs compared to the costs for dairy cows [4]. In addition to those mentioned above, it is necessary to mention that animal husbandry specialists have highlighted a very important fact in terms of cattle for meat, namely, that they have a very high capacity to convert fodder into meat [1, 5].

Photo 1. Cattle
Source: [6].

## MATERIALS AND METHODS

The paper presents the main trends for the world beef market in the period 2015-2020. In order to highlight the evolution of the beef market in the world, several specific indicators were presented and analyzed as follows: cattle herds worldwide; beef and veal production worldwide; beef consumption worldwide; global imports and exports. In order to elaborate this study, a variety of statistical data were used, which were taken from the FAOSTAT website and from other specialized sites. The main results of the research were presented mainly graphically, but also in a tabular form.

## RESULTS AND DISCUSSIONS

Worldwide, in the period under review for the beef market, a number of beneficial changes were visible, which contributed to meeting consumer demand to a greater extent. This was possible, on the one hand, due to the efforts of the actors involved in the production and marketing of beef, and on the other hand, due to the strategies and solutions identified for this important sector of activity. The first milestone from which it is necessary to carry out the analysis of the beef market at a global level is represented by the total bovine population. From the statistical data presented for the period 2015-2020, it is easy to notice that the number of cattle worldwide was on an upward trend (Fig. 1).

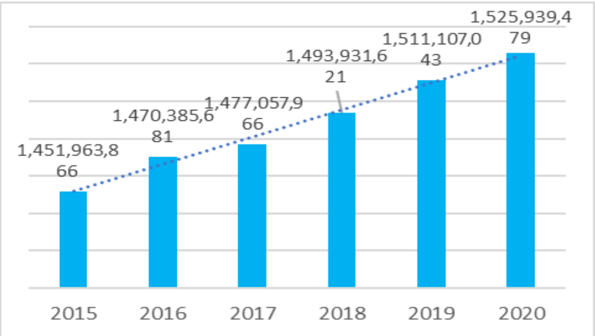


Fig. 1. Cattle herds worldwide, for the period 2015-2020 (heads)
Source: Own design based on FAOSTAT database [7].

The smallest bovine herd was registered in 2015 (1,451,963,866 heads), and the largest had 1,525,939,479 heads (2020). From the analysis of the cattle herd, it resulted that it recorded an increase at global level by 5.09% in 2020, compared to 2015.

Worldwide, in the period 2015-2020, the production of meat of cattle with the bone, fresh or chilled has evolved differently as follows: in the period 2015-2019, it has been on an upward trend. Starting with 2020, it began to decrease compared to the previous year (Fig. 2).

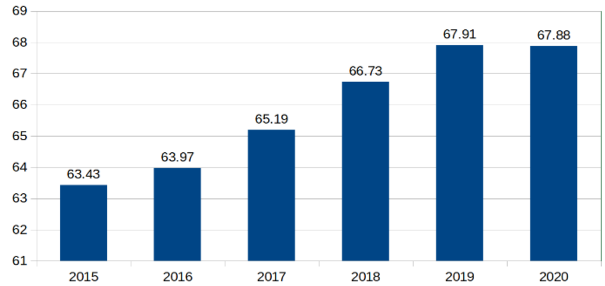


Fig. 2. Production of cattle meat with the bone, fresh or chilled, worldwide, in the period 2015-2020 (million metric tons)
Source: Own processing of FAOSTAT data [7].

From the statistical data presented in Figure 2 it can be observed that the smallest production of meat of cattle with the bone, fresh or chilled worldwide, was obtained in 2015 (63.43 million metric tons), and the highest was of 67.91 million metric tons (2020). According to FAOSTAT data, in 2020, the production of meat of cattle with the bone, fresh or chilled worldwide, decreased by 32.527 tons compared to 2019. Also, in 2020, the production increased by 4,448,744 tons, compared to 2015 [7]. It is important to specify that the production of beef in the analyzed period suffered a series of oscillations that were determined, mainly by: the number of cattle for meat; meat consumption recorded worldwide; the price of feed, the price of labor force and prices for beef on the international market [2].

At continental level, in 2020, America is the largest producer of meat of cattle with the bone, fresh or chilled, achieving 48.6% of the production obtained worldwide. At the opposite pole, the smallest production is obtained by Oceania, with only 4.5% of the world's beef and veal production. In 2020, Oceania achieved only 9.3% of the meat of cattle with the bone, fresh or chilled, obtained by Americas (Table 1, Fig. 3).

Table 1. Production of meat of cattle with the bone, fresh or chilled, at continental level, in 2020

| Crt. no. | Region | Production in absolute value (tons) | % of worldwide production |
|---|---|---|---|
| 1. | Americas | 33,005,224 | 48.6 |
| 2. | Asia | 15,310,274 | 22.6 |
| 3. | Europe | 10,515,871 | 15.5 |
| 4. | Africa | 5,965,965 | 8.8 |
| 5. | Oceania | 3,085,763 | 4.5 |

Source: [7].

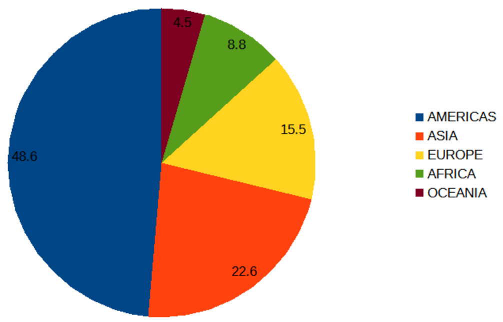


Fig. 3. Production share of meat of cattle with the bone, fresh or chilled at continental level, in 2020
Source: Own design based on FAOSTAT database [7].

In 2020, according to the official data published, on the first place in the worldwide top of the largest producers of meat of cattle with the bone, fresh or chilled, was the United States of America with a production of 12.3 million metric tons (Fig. 4). The second place is occupied by Brazil with 10.1 million metric tons. It managed to produce 82.1% of the meat of cattle with the bone, fresh or chilled, obtained by the United States. Third place was occupied by China with a production of 6.0 million metric tons.

Photo 2. Beef
Source: [10].

Argentina ranked 4th, and produced 51.6% of China's obtained production. Australia ranked 5th among the largest producers of meat of cattle with the bone, fresh or chilled, since 2020. It accounted for only 18.3% of the production obtained by the United States. The global consumption of beef and veal in the period 2015-2020 recorded increases from one year to the next. The lowest consumption was recorded in 2015 (66,223 thousand tons), and the highest was of 70,882 thousand tons (2020). The consumption of beef and veal increased worldwide in 2020, by 7.03% compared to 2015 (Fig. 5).

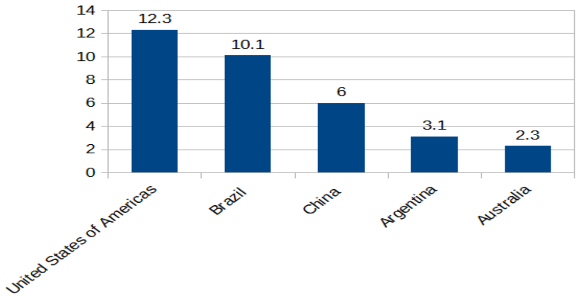


Fig. 4. Top 5 major producers of meat of cattle with the bone, fresh or chilled, worldwide, in 2020 (million metric tons)
Source: Own processing of FAOSTAT data [7].

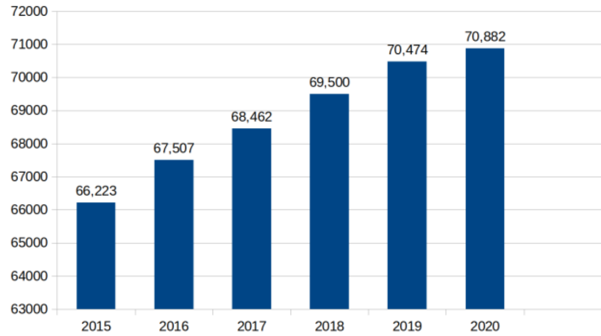


Fig. 5. Beef and veal consumption, for the period 2015-2020 (thousand tons)
Source: [9].

For the period 2023-2029, the total consumption for the "Beef and Veal" category at global level will be on a positive trend. It will increase from 72,149 thousand tons (2023) to 75,728 thousand tons (2029) (Fig. 6). The consumption of beef and veal in 2029 will increase by 4.96% compared to 2023. The increase in consumption will be influenced, on the one hand, by the population growth, and on the other hand, by the characteristics of this type of meat so appreciated by consumers.

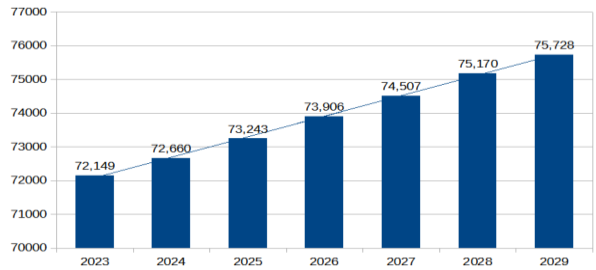


Fig. 6. Forecasts regarding the consumption of beef and veal, in the period 2023-2029 (thousand tons)
Source: [9].

Regarding the consumption of beef and veal per capita, worldwide, in 2015, according to the official data published, it was of 6.3 kilograms/capita, and in 2020, it increased insignificantly reaching 6.4 kilograms/capita [9].

In 2020, the highest per capita consumption of beef and veal was recorded in Argentina, with 36.9 kilograms (Fig.7). Argentina occupies the first position in terms of beef and veal consumption per capita, among the top 5 countries registered worldwide. The second place in this ranking is occupied by the United States with 26.2 kilograms/capita. Here, the amount of beef and veal consumed per inhabitant represents only 71.0% of the consumption recorded in Argentina. The third place is occupied by Brazil with a consumption of 24.4 kilograms/capita (66.1% of the per capita consumption of Argentina).

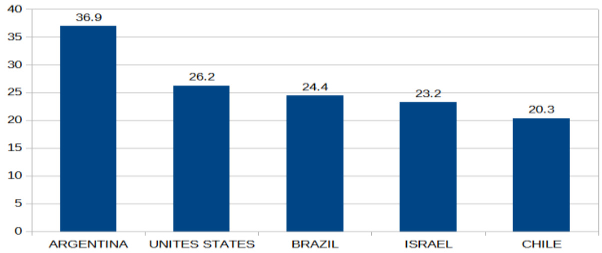


Fig. 7. Top 5 major consumers of beef and veal recorded worldwide, in 2020 (kilograms/capita)
Source: Own graphics after the data taken from OECD [9].

The 4th place is occupied by Israel, with 23.2 kilograms per capita. The 5th place in the ranking mentioned above is occupied by Chile, with 20.3 kilograms/capita (55.0% of the consumption per capita highlighted in Argentina).

For the year 2029, a world consumption of beef and veal of 6.3 kilograms/capita is expected. The estimated consumption for 2029 will be equivalent to the consumption in 2015, and will decrease by 1.6% compared to 2020 [9].

According to the forecasts for 2029, the ranking of the first 5 major consumers of beef and veal will consist of the following countries: Argentina (36.0 kilograms/capita); United States (26.0 kilograms/capita); Brazil (24.4 kilograms/capita); Israel (25 kilograms/capita) and Chile (21.8 kilograms/capita) (Fig. 8). This ranking has not changed compared to the ranking obtained for 2020, in terms of the place occupied by the top 5 countries that consume beef and veal. Changes occurred in terms of beef and veal consumption per inhabitant in the countries mentioned above, in 2029, compared to 2020, as follows:

-Argentina - beef and veal consumption per capita will be reduced by 2.5%;

-United States - consumption will decrease insignificantly, by only 0.2%;

-Brazil - consumption will remain constant;

-Israel - consumption will increase by 3.8%;

-Chile - consumption will increase by 7.3%.

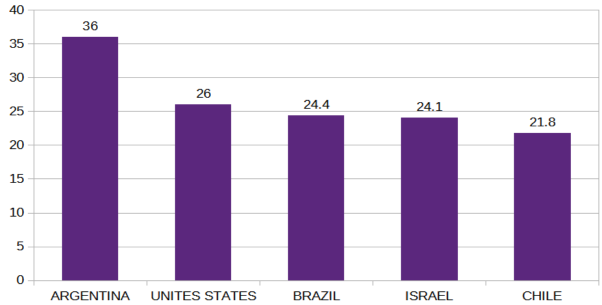


Fig. 8. Top 5 major consumers of beef and veal recorded worldwide, in 2029 (kilograms/capita)
Source: Own graphic using the data from OECD [9].

In the period 2015-2020, global quantitative imports for the "Beef" category recorded a number of changes. The most significant imports of beef worldwide were obtained in 2018 (2,910,517.00 tons), and the lowest were of 1,882,174.26 tons (2019) (Fig. 9). From the data presented, it is found that imports of beef recorded worldwide, increased from 2,435,018.00 tons (2015) to 2,673,865.14 tons (2020).

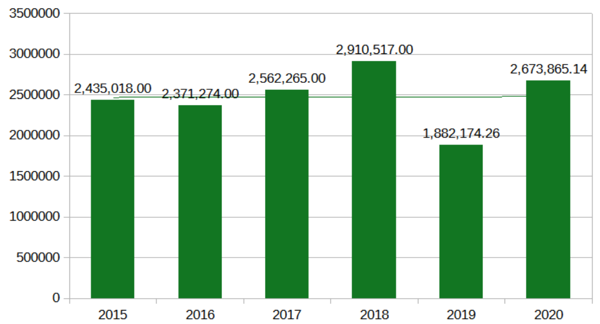


Fig. 9. Quantitative imports of beef at global level, in the period 2015-2020 (tons)
Source: Own graphics according to the data taken from Faostat [7].

In 2020, global beef imports decreased, compared to 2018, when the peak was reached, by 8.2%.

Worldwide, according to the data provided by Faostat, in 2020, the most significant importers for the category "Meat of cattle with the bone, fresh, or chilled" were: China (297,017 tons, respectively 11.1% of world imports); The Netherlands (229,062 tons, respectively 8.5% of world imports); Italy (200,080 tons, respectively 7.4% of world imports); Republic of Korea (155,081 tons, respectively 5.7% of world imports) and The United States of America (125,604 tons, respectively 4.6 of world imports). In 2020, the first 5 importers for the category "Meat of cattle with the bone, fresh, or chilled" presented above accounted for 37.3% of the imports obtained worldwide (Fig. 10).

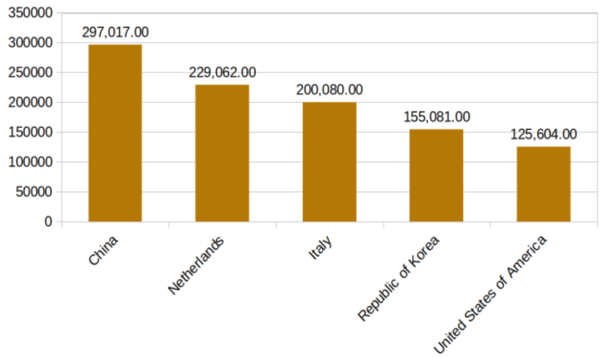


Fig.10. The top 5 major importers registered worldwide for the category "Meat of cattle with the bone, fresh, or chilled" in 2020 (tons)
Source: Own graphics according to the data taken from the Faostat [7].

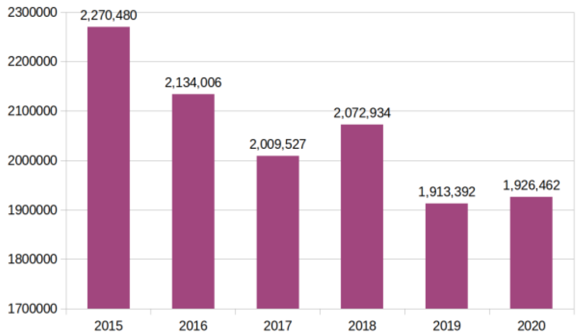


Fig.11.Quantitative exports of beef produced worldwide, in the period 2015-2020 (tons)
Source: Own graphics according to the data taken from Faostat [7].

Worldwide, during the analyzed period, it was found that global quantitative exports for the "Beef" category have changed from one year to another. The largest exports of beef recorded worldwide were in 2015 (2,270,480 tons), and the lowest were of 1,913,392 tons (2019) (Fig. 11). In 2020, world beef exports decreased by 15.2% compared to 2015. This situation was mainly due to the global health crisis.

According to the data provided by Faostat, in 2020, the most significant exporters registered worldwide for the category "Meat of cattle with the bone, fresh, or chilled" were: Poland (196,825 tons, respectively 10.2% of world exports); The Netherlands (162,975 tons, respectively 8.4% of world exports); France (148,182 tons, respectively 7.6% of world exports); Spain (143,253 tons, respectively 7.4% of world exports) and Germany (136,524 tons, respectively 7.0% of world exports) (Fig.12). At the level of 2020, the first 5 major exporters for the category "Meat of cattle with the bone, fresh, or chilled" presented above recorded 40.6% of the worldwide exports.

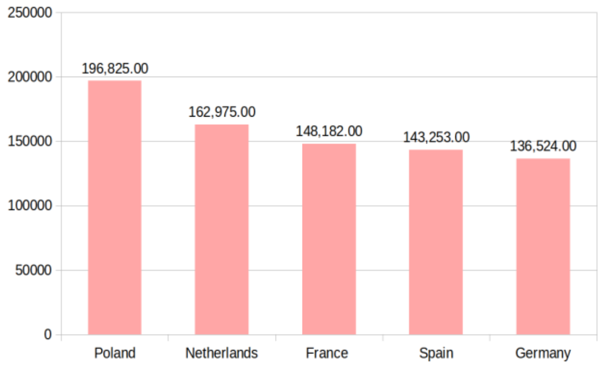


Fig. 12. The top 5 major exporters registered worldwide for the category "Meat of cattle with the bone, fresh, or chilled" in 2020 (tons)
Source: Own graphics according to the data taken from Faostat [7].

From the data presented it is easy to notice that the first 5 major exporters are part of the European Union. This fact proves that the European Union is a significant producer of beef and veal, with livestock of about 78 million cattle. It is necessary to remember an important aspect, namely, that in the European Union farmers are helped through income support payments [12].

The value of imports for the "Beef" category recorded worldwide, increased from

8,962,804 thousand dollars (2015) to 9,372,034 thousand dollars (2020) (FAOSTAT). Regarding the value of imports for beef, they increased in 2020 by 4.5%, compared to 2015.

Regarding the value of exports for the "Beef" category, they decreased from 8,604,054 thousand dollars (2015) to 8,459,361 thousand dollars (2020). The value of exports decreased in 2020 by 1.7%, compared to 2015.

According to official data, the global beef market is expected to grow from 414.98 billion dollars (2022) to 604.34 billion dollars by 2029 [3].

## CONCLUSIONS

Following the analysis of the main indicators related to the beef market worldwide for the period 2015-2020, the following results emerged:

-In 2020, the most significant cattle herd was registered, 1,525,939,479 heads;

-The highest production of meat of cattle with the bone, fresh or chilled, obtained worldwide, was registered in 2020 (67.91 million metric tons);

-Americas, in 2020, was the first ranked at the continental level, in terms of meat of cattle with the bone, fresh, obtaining 48.6% of the total beef production;

-The largest producer of meat of cattle with the bone, fresh or chilled, worldwide, was represented by the United States of America with 12.3 million metric tons (2020);

-The highest consumption of beef and veal in the world was of 70.882 thousand tons (2020);

-The highest consumption of beef and veal per capita in the world was of 6.4 kilograms (2020);

-Argentina in 2020 registered the highest consumption of beef and veal per capita, of 36.9 kilograms;

-In 2018, the highest imports of beef were recorded worldwide, of 2,910,517.00 tons;

-China, in 2020, was the largest importer of cattle with the bone, fresh or chilled, registered worldwide, with 297,017 tons;

-In 2015, the most significant exports for the "Beef" category of 2,270,480 tons were highlighted worldwide;

-In 2020, Poland was the largest exporter for the category "Meat of cattle with the bone, fresh or chilled", with 196.825 tons;

-The value of imports for beef worldwide increased by 4.5% in 2020, compared to 2015;

-Value exports for beef worldwide decreased by 1.7% in 2020, compared to 2015.

According to official estimations, in the year 2029, the global beef market is expected to grow to 604.34 billion dollars.

## ACKNOWLEDGEMENTS

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# RESEARCH REGARDING THE IDENTIFICATION OF THE FUNGUS *PHOMOPSIS MALI* ROBERTS (*PHOMOPSIS* FRUIT TREE CANKER) IN A TWO YEARS OLD ECOLOGICAL APPLE ORCHARD - CASE STUDY

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***Abstract***

*Phomopsis mali Roberts (Phomopsis fruit tree canker) is a fungus that infects the fruit tree trunks, branches and sprigs. There were described more than 60 species of Phomopsis. Every of the species is identified in general after the size of the conidia and after the host from which was isolated, the precise identification being sometimes difficult. Phomopsis is a fungus that can produce serious damages in production because it affects the fruitful sprigs. On the other hand, in case of massive attacks it can lead to the fruit trees decline. In the young orchards cultivated in ecologic super-intensive system, the young trees can die in the case of severe infections. The purpose of this research was to identify the Phomopsis fungus in an ecologic super-intensive apple orchard from Arad County (western Romania), in the first two years after the plantation. The biological material used was consisting in six samples sets (sprigs, stems, branches and roots) collected from four apple varieties (Primiera/$M_9$, Crimson Crisp/$M_9$, Golden Orange/$M_9$ and GoldRush/$M_9$). The identification of the disease and of the pathogen was done using visual and laboratory methods. In laboratory was identified the fungus with the humid chamber method and by placement of diseased tissue samples on culture medium followed by incubation at 23 - 24ºC for seven days. The branches, sprigs and stems were analysed at stereomicroscope too. Under the cracked bark were identified numerous pycnidia of black colour and pear shaped, specific to the Phomopsis mali fungus. There were noticed young and old fructifications, the old ones were from the previous year or even from the precedent years. The obtained results after the visual analysis of the trees in the orchard and after the laboratory analyses highlighted the presence of the fungus Phomopsis mali. There were highlighted at the microscope the alpha and beta conidia, typical for this fungus. In the orchard all the trees were presenting symptoms specific to the Phomopsis fruit tree canker. The trees covered with numerous canker lesions were died. At the assessment time the dead trees rate on varieties was the following: Primiera – 16.5%, Crimson Crisp – 1.7%, Golden Orange – 16.1%, and Gold Rush – 17.2%. From all the analysed apple varieties only Crimson Crisp had reacted well to the attack of the Phomopsis mali fungus.*

***Key words****: Phomopsis mali, apple, varieties, pycnidia, Phomopsis fruit tree canker, ecologic orchard*

## INTRODUCTION

*Phomopsis* fruit tree canker is produced by the fungus *Diaporthe perniciosa* Marchal sin. *Diaporthe eres* Nitschke (sexual life cycle), with the conidian form or asexual life cycle *Phomopsis mali* Roberge, sin. *Phomopsisperniciosa* Grove. The fungus *Phomopsis mali* is famed from taxonomic point of view in the Kingdom *Fungi*, Phylum *Ascomycota*, Class *Sordariomycetes*, Order *Diaporthales*, Family *Diaporthaceae*, Genus *Phomopsis* (Sacc.) Bubák 1905, Species *Phomopsis mali* (Schultzer & Sacc.) Died.

(syn. *Phomopsis prunorum* (Cooke) Grove [10][18]. Even the scientific community recommends the use of the name *Diaporthe* for *Phomopsis*, in practice is used most often the name *Phomopsis* because the anamorph stage of the fungus is found more often in nature instead the teleomorph one [23]. According with Shenoy *et al*. [27], the use of two names for the same pathogen is useless and can lead often to confusions. Thus, the name of the anamorph stage is used in practice very often for other pathogens too [31].

*Phomopsis* fruit tree canker produced by the fungus *Phomopsis mali* on apple tree is a disease found more and more often in the young orchards from western Romania cultivated in ecological system. The symptoms produced by the pathogen are recognized relatively easily, but many times they are confused with those produced by *Cytospora* sp., *Botryosphaeria* sp. or even by *Erwinia amylovora* [19][7].

In the case of apple trees, *Phomopsis mali* attacks the sprigs, branches stems, and fruits [15]. At the surface of the attacked organs can be noticed a change of the bark colour becoming reddish – orange or even blackish in advanced phases of the pathogen evolution. The first necroses appear in the area of the vegetative buds, floral buds but also of the petioles area. Together with these symptoms can be observed the appearance of depressed areas in the bark with an irregular shape that often cracks (cankers). In massive attacks the fungus passes from bark the wood entering in the vascular tissues and the attacked organs are fading first and later will have a burn appearance [21][24][14]. The necrosed sprigs and branches are visible from distance. Exceptionally, in the very severe cases the fungus can enter even in thick trunks and branches. In the young trees *Phomopsis mali* can enter very easily in the wood of the thin stems, killing them [21][15][28][25]. When are forming the fruiting bodies (pycnidia and perithecia), at the surface of the bark appear small swellings that are giving a rugous aspect to the attacked organs [21][15].

The pycnidia and the perithecia are developing in the infected tissues. The perithecia (teleomorph fruiting bodies) are forming rarely in nature in comparison with the pycnidia (anamorph fruiting body) that are observed more frequently. Both fruiting bodies types are important in the identification of the species *Phomopsis* that has produced the disease together with the host [31][1]. The pycnidia have ostioles, are black, pear shaped and are producing two types of conidia: alpha (aseptate, spindle like, hyaline, guttulate or not-guttulate) and beta (aseptate, filiform, hyaline, not-guttulate) [8][29][20][6]. In conditions of humidity the pycnidia are releasing a mucilaginous mass white in colour at the beginning, full of spores, that in contact with the air is solidifying and can take different shapes. In the presence of water, the spores will produce new infections.

The perithecia can appear solitaire or in groups and are sunken into the substrate. The asci from the inside are unitunicate, clavate and contain ascospores that can have different shapes from spindle like, elliptic, linear, cylindric or curved. The ascospores are hyaline and septate [33][13][17][15].

*Phomopsis* fruit tree canker can evolve during the entire year in favourable climatic conditions, but especially during the summer and autumn when can be registered maxim attack intensities [21][15][32][26].

In general, all the species of *Phomopsis* are producing infections in conditions of cool weather (temperatures between 15 - 24 $^{o}$C) and rainy weather (rain helps the production of the spores, dispersion and initiation of the infection) [15][26]. Over the winter season the pathogen survives in the infected organs, mostly in branches and sprigs. There was noticed that in the perennial herbaceous plants the fungus can overwinter on senescent leaves and fruit remains. According with Schilder [26], often the pathogen can reach in orchard with the planting material. The climate conditions in continuous change, the neglecting of the prevention methods (mostly phytosanitary hygiene), are favouring the infections with *Phomopsis* in the young apple orchards cultivated in ecological system [7][2][9].

There is interesting the fact that numerous *Phomopsis* species have potential in the control of the invasive weeds from agricultural crops. The myco-herbicide effect is due to their hemi-biotrophic till to necrotrophic living, their capacity to persist in the environment and due to its extended sporulation during the entire duration of a year [16][3][22][4][30].

The control of the *Phomopsis* tree canker of the apple tree is difficult when the pathogen is already installed, mostly for the very young trees in the second year of life. In such situations the pathogen can enter in the stems with small diameter. There is recommended the harmonious jointing of the cultural hygiene measures (destroying of the diseased biological material) with the chemical methods (use of fungicides). There are vital the treatments applied in spring (at the budding phenophase) and those applied in autumn (October, after the fruit harvesting and after the leaf fall [26]. For a good control of the disease is necessary the early diagnosis of the fungus. The right identification of the *Phomopsis* species is based mainly on morphological and cultural features and the association with the host, but sometimes is difficult to realise it. Why is necessary the precise identification of the pathogen? For the elimination of the confusions with other pathogens and for the setting of the proper control measures[5][24][11][12][31].

The branch canker produced by the fungus *Phomopsis* sp. is more and more present in the last years in the nurseries and orchards from Romania. Very young orchards of one or two years are diseased, some being even in the very severe situation when nothing can be done to save the plants, mostly where they are cultivated sensitive varieties. The most severe problems are in the ecologic orchards created with diseased planting material.

The approached topic from this work is very actual and is very interesting for the fruit growers that are confronting more often in the last years with this disease.

The main purpose of this study was the correct identification of the pathogen from a young apple orchard cultivated in super-intensive ecologic system, from western Romania. There were applied laboratory analyses that were done on sections of diseased tissue and their introduction in humid chambers where the evolution of the fungus was analysed.

## MATERIALS AND METHODS

The biological material was sampled directly from an apple orchard from Arad County in April 2021 (Photo 1). The apple orchard is cultivated in super-intensive ecologic system (2000 trees/hectare) and it was planted during the years 2019-2020. There were collected samples from plants consisting in branches, trunks, sprigs and roots (entire plants) from every variety cultivated in the orchard, respectively Primiera, Crimson Crisp, Gold Orange and GoldRush. The samples were brought in the laboratory where first were analysed at stereomicroscope. The photographs were taken with a Nikon camera with micro-objective. The frequency of the dry trees due to the disease was set by their counting ant reporting to the total number of the analysed trees. In the same time there were analysed and photographed the external symptoms at every 20 trees from every variety.

Photo 1. Aspect from the apple orchard during the sample collection (in Arad County, Romania).
Source: Original photo by Cotuna O. (2021).

Parts of sprigs, branches and stems were studied at the stereomicroscope for the observation of the specific fruiting bodies (pycnidia).

The humid chamber method was used for the stimulation of the pycnidia to release the mucilaginous masses in which are forming the conidia of the fungus *Phomopsis mali*. In this way, there were cut segments of sprigs, stems and branches with the length of about 10 cm.

They were washed with tap water and after that were rinsed with distilled water. The sterilization on surface of the plant segments was done using sodium hypochlorite 3% (1 minute) and ethylic alcohol 96% (1 minute). The rinsing was done with distilled water for 2 minutes. The segments prepared in this way were placed in humid chambers and incubated at 24 - 25 $^{o}$C for several days. the humid chambers were done in plastic dishes (20/10 cm) with sterile filter paper on which was dropped sterile water. After two days the pycnidia from the tissues from the humid chambers were erupted and were released mucilaginous masses specific to the analysed pathogen. With the sterile needle were extracted drops of mucilage that were introduced in lactophenol blue and were analysed at the microscope (Axion Zeiss).

In parallel from the infected tissues were detached pycnidia that were placed directly in lactophenol blue and left there for an hour. Through this simple method there was possible to analyse at the microscope in a shorter time the alpha and beta conidia of the pathogen.

## RESULTS AND DISCUSSIONS

The partial identification of the pathogen present in the apple orchard was done with the occasion of a phytosanitary control. With this occasion was noticed that the apple trees have obvious signs of disease manifested on stems, branches and sprigs. The symptoms aspect was as rugous dry cankers on the bark surface. Due to the obvious symptoms noticed on sight the suspected pathogen was the fungus of *Phomopsis* tree canker *Diaporthe eres* Nitschke (sin. *Diaporthe perniciosa* Marchal, teleomorf form) with the anamorph form *Phomopsis perniciosa* Grove (sin. *Phomopsis mali* Roberge).

The trees from the orchard were presenting symptoms specific to *Phomopsis sp.* in different evolution stages. Also, at the spring break many trees with symptoms of Phomopsistree canker were died. The dead trees were covered in totality by rugous cankers, cracks, under those were hundreds of black pycnidia that will spread the pathogen on the new grown parts of the young trees. It is well known that this pathogen produces infections during the entire year, with a higher intensity during the summer and autumn months.After the evaluation proceeded in the apple orchard, the rate of dead trees found was the following: Primiera - 16.5%; Crimson Crisp - 1.7%; Golden Orange - 16.1% and GoldRush - 17.2% (Figure 1).

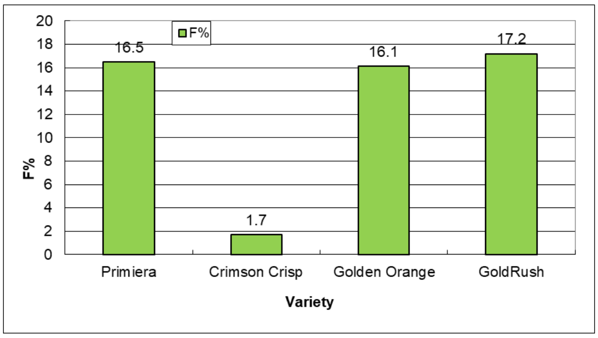


Fig. 1. Frequency of the dead apple trees due to the pathogen *Phomopsis mali* in April 2021 (%)
Source: Original graph generated on the base of the calculated experimental values.

There was noticed that in the variety Crimson Crisp the frequency of the dead apple trees is very low in comparison with the other apple varieties cultivated in the orchard. In the other varieties the frequency of the dead trees has varied between 16.1 % and 17.2 %.

The visual analysis of the symptoms in the samples of 20 trees from every variety was highlights several types of symptoms: sunken spots with dark colour in the bark tissue (located in the dud area and the petiole scars); open wounds with calluses on the edges located at the joint of the branches, on trunk and on the sprigs from the previous year with canker aspect; dead branches (necrosed) presenting ulcerations (the bark of the branches has rugous aspect); bark with colour changes (orange – brick red, black, grey); deformation and swelling of the bark (initial symptoms produced by the pathogen); in the areas with swollen bark, under the bark were found dozens of fruiting bodies of the fungus; old ulcerations, rugous, verrucous, black (at their surface were placed the black coloured fruiting bodies of the fungus); blacken xylem tissue in section; cracks in the bark tissue from the branches (in the cracks were small black bodies, respectively the fungal pycnidia); great parts of ligneous tissue browned in trunks and branches joints; the sprigs with healthy appearance were having browned areas under the bark that was surrounding the buds; the cortical tissue of the roots was rotten and was brown in colour in transversal section; radicular system with obvious diseased signs (browning); browning of the central cylinder of the lateral root system (Photo 2-8).

Photo 2. Swollen bark, reddish and with young fructifications specific to the fungus *Phomopsis mali*.
Source: Original photo by Cotuna O. (2021).

Photo 3. Bark with rugous appearance
Source: Original photo by Cotuna O. (2021)

4 5

6 7

Photo 4 - 7. Reddish – orange bark, rugous, cracked, xylem necrosis.
Source: Original photo by Cotuna O. (2021).

Photo 8. Necrosed wood of the apple tree stem.
Source: Original photo by Cotuna O. (2021).

At steremycroscope were analysed the branches, sprigs and stems. There were observed the open lesions, the cracks from the bark and the swellings.
Under the cracked bark were present numerous pyriform black pycnidia characteristic to the fungus *Phomopsis mali*. There were noticed young and old fructifications, the old ones being produced in the previous years (Photos 9 – 15).

Photo 9. Agglomeration of pycnidia under bark
Source: Original photo by Cotuna O. (2021).


10 11


12 13

Photo 10 - 13. In the presence of humidity from the pycnidia were expulsed white-cream mucilaginous masses. In contact with the air takes different shapes
Source: Original photo by Cotuna O. (2021).

Photo 14. Young pycnidia.
Source: Original photo by Cotuna O. (2021).

Photo 15. Pycnidia in formation.
Source: Original photo by Cotuna O. (2021).

Photo 16. Alpha and beta conidia at the microscope (x40)
Source: Original photo by Cotuna O. (2021).

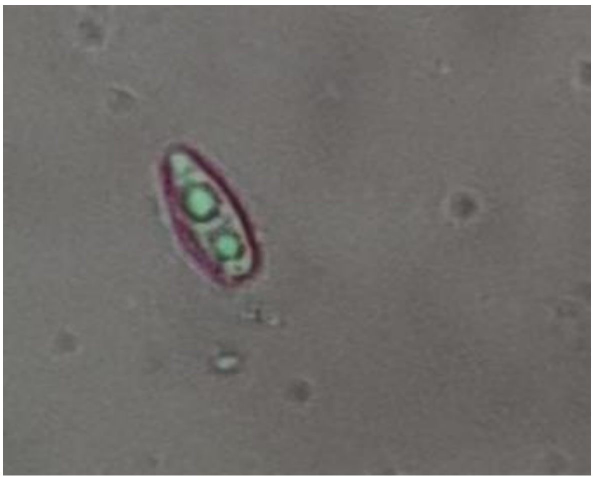

Photo 17. Alpha conidia at the microscope (x40).
Source: Original photo by Cotuna O. (2021).

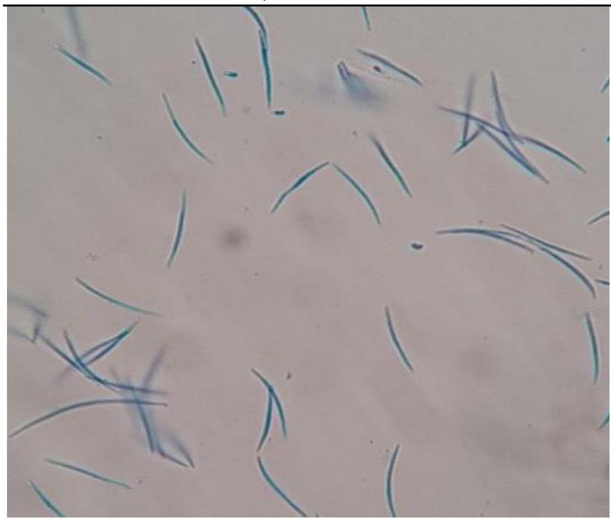

Photo 18. Beta and alpha conidia at the microscope (x40)
Source: Original photo by Cotuna O. (2021).

laboratory analyses is confirmed the diagnosis of *Phomopsis* tree canker produced by the fungus *Phomopsis mali***.**The correct diagnosis is necessary to exclude other fungi that are producing similar symptoms (*Botryosphaeria* sp., *Cytospora* sp.).

We cannot know for sure if the *Phomopsis* species identified in this research is certainly *Phomopsis mali*. Thus, the external symptoms, the host, the present fructifications, the shape of the conidia, the colour of the gelatinous masses that were drained from the pycnidia are conducting us to this species, although quite present in the orchards from Romania.

The pathogen *Phomopsissp*. is a destructive fungus, with potential in production of important loses in the fruit yield (the spur sprigs are killed by the disease). In the very severe situations, with high attack intensities the trees will be in decline. The most severely affected can be the young ecological plantations where the plantings will die. For the *Phomopsis sp.* fungus the tree age doesn't matter. The pathogen can attack at any age of the three. Sometimes it sets even in the young trees from the nurseries.

## CONCLUSIONS

After the proceeding of analyses from the field and from the laboratory we can assume that the pathogen identified in the apple tree orchard from Arad County cultivated in ecological system is a species of *Phomopsis*, possibly *Phomopsis mali*.

The most attacked apple variety was GoldRush, followed by Primiera and Golden Orange. In these varieties the trees were died in a rate between 16-17%. The young ecological orchards are susceptible to the attack of the destructive pathogens as is *Phomopsis* sp. The control possibilities in these orchards are practically inexistant, because the application of the chemical substances is forbidden and the biological treatments doesn't have curative effect.

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# SOME METHODS FOR COMPOSTING ORGANIC WASTE AND PRESERVING ENVIRONMENT AND SOIL BIODIVERSITY-A REVIEW

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***Abstract***

*The article reflects the problem of organic waste management and the composting methods used to improve the ecological situation of the environment. Some methods of composting organic waste of various origins are synthesized. Composting represents the process of decomposition and transformation of solid organic substances by microorganisms (mainly bacteria and fungi) into a stable material, which can be used (depending on the characteristics), in agriculture, instead of chemical fertilizers or in land improvement works (soil improvement). Only some methods of composting are characterized: the traditional method, worm cultivation and the method of effective microorganisms. All composting methods are welcome for agriculture because they solve complicated environmental problems: complete processing of organic waste, obtaining organic fertilizers and ecological agricultural production and improving the ecological situation.*

***Key words*****:** *composting, efficient microorganisms, organic waste, traditional composting, worm cultivation*

## INTRODUCTION

At the current stage, nature can no longer be saved and protected only by mischievous actions. The protection of the environment involves all global, regional, national and local actions aimed at preserving, rationally using and reproducing the nature of the Planet. Through cooperation, humanity adopts political decisions, legal acts, develops new technologies, performs collective and individual actions in the field of environmental protection. All these actions were concentrated in a concept of sustainable development, which is ecological in nature and has beneficial consequences on the improvement of the environmental situation.

Biodegradable rural waste differs from urban waste in composition and quantity. The lack of public sanitation services in the rural area and the primary record of waste generation makes it impossible to compile correct and timely statistics of rural biodegradable waste

The livestock sector generates animal waste and from birds, constituting a significant amount of biodegradable waste. Animal husbandry enterprises and large farms breeding animals and birds, in the public and private ownership of economic agents, as well as the small ones within the peasant households produce large amounts of waste and manure that require specific systems for their management, both at the local and regional level.

Manure was, is and will always remain a debatable topic. On the one hand, it is a waste that animal breeders want to get rid of, on the other hand, if it is not stored and used domestically, according to the requirements, it is a very dangerous factor of water pollution, both surface and to those in the groundwater. However, manure is an important resource for farmers, constituting a material that makes a particularly important contribution to restoring the humus layer, which chemical fertilizers cannot do.

Animal husbandry in rural areas has generated intensive pollution of the soil, underground water, phreatic wells and surface water. The collection and separate storage of waste from the livestock sector remains one of the biggest problems, considering that not all farmers are aware of the need to separate it, especially those who have not yet decided to safely store all the residues produced by animals. Taking into account the fact that in the zootechnical sector the share of livestock has moved from the public to the private sector (85-97%) with unfavorable consequences of environmental pollution, it is recommended to all specialists to pay major attention to the management of animal manure. The amount of accumulated animal manure varies depending on the species of animals, their age, their number and the duration of the maintenance period in the stable [10].

The correct management of manure is done by setting up storage systems that can be individual (household), communal or a combination of the two. Right from the design stage of farms and the construction of manure storage capacities, it is necessary to pay special attention to the prevention of pollution, especially of water and environmental protection

Where the organic waste management plan is established in accordance with specific local conditions (soil type, distance to water sources, land slope, volume of precipitation, farm system and duration of storage periods) manure is managed correctly, without the risk of to cause environmental pollution. Manure must be kept in platforms, packed, covered with a layer of soil 15-20 cm thickness. In order to decompose, the garbage must have a humidity of 70-75%, otherwise it will dry out and mold. Before being covered with earth, the garbage is watered with garbage must, urine or even water to ensure the necessary moisture, improve the composition and reduce nitrogen losses [11].

## MATERIALS AND METHODS

Material for the research served both literary sources in which the ecological problems in the livestock sector and phytotechnology sector are exposed, as well as our own research regarding the management of organic waste and the methods of solving these problems [2], [4], [5], [6]. As a result of the analysis of the studied materials, observations and own research, some methods of composting organic waste from the zootechnical sector were highlighted, in order to make it possible to use it as organic fertilizer in the phytotechnology sector.

## RESULTS AND DISCUSSIONS

### Composting: definition and importance

Composting can be defined as a controlled biological process of conversion and valorization of residual organic materials (biomass by-products, organic waste of biological origin) in a stabilized, hygienic, soil-like product, rich in humic compounds. Composting (the act of fermenting various organic residues in the presence of oxygen in the air) is a millennial empirical practice in agriculture and horticulture that has returned to the fore with technologies for processing and restoring what we now call biomass.

In the literary sources, data are presented regarding the importance of organic material, which is contained in biodegradable organic waste.

Michel Musten mentions that in the search for an autonomous and diversified agriculture, the use of organic waste is welcome. The progress of ecological ideas foresees a revival of agriculture that requires the search, renewal or discovery of methods of management and improvement of organic products. Traditionally used, various organic wastes (agricultural, agrifood, industrial, household, forestry, etc.) are no longer processed or processed unsatisfactorily. The level of humus in soils decreases, by increasing erosion and drought. For the management of organic waste in order to effectively combat pollution, new technologies have been developed, the so-called ecological technologies. Michel Musten's research in the field of biodegradable organic waste processing is very useful for all farmers, gardeners, horticulturists, government engineers and technicians, organic agrifood producers, amateur horticulturists, teachers and students [13].

In the works of G. Gigliotti et al., [11] it is mentioned that composting means recycling the organic matter and regulating the natural cycles that were interrupted by the abandonment of traditional agricultural practices.

At the same time, it is mentioned about composting that: it is a technique of stabilization and aerobic treatment of biodegradable organic waste; addresses all organic waste, but especially solid and semi-solid waste; is a way to destroy the seeds of unwanted plants (weeds), and by means of heat and different internal factors, pathogenic germs and different parasites, carriers of various diseases, can be destroyed; it is a biological technique for recycling organic matter which, along its evolution, leads to the production of humus, a stability and fertility factor for soils; it is the result of a very complex microbiological activity, occurring under specific conditions.

G. Gigliotti et al., mention that the composting process helps to manage very large amounts of organic waste in a sustainable manner. Composting is one of the technologies that make up integrated waste management strategies, used to recycle organic matter into a useful product [11].

Composting is a well-known system for the rapid stabilization of organic matter. The application of compost, obtained from a wide variety of human activities, to arable soils is in the attention of scientists worldwide with the goal of increasing the content of organic matter. Although the transformation of organic matter during the composting process has been widely studied, most reports have focused on the humic fraction. The dissolved organic matter compost is a mixture of specific low molecular weight compounds (amino acids and sugars) and chemically heterogeneous high molecular weight polyelectrolytes (enzymes, amino-sugar complexes, polyphenols and humic-like substances). Because most of the biogeochemical transformations that are part of the evolution of organic matter during composting occur in solution, this being dissolved represents the most active fraction of compost, both biologically and chemically. Therefore, dissolved organic matter is the organic fraction most subjected to changes and, as such, should directly reflect the process of organic matter transformation. In fact, the chemical transformations that occur in the dissolved organic matter fraction of the compost could provide important indications regarding the evolution and stabilization of the transformation process during composting, as well as at the maturity of the final compost.

The involvement of dissolved organic matter in chemical and biochemical processes of soil after fertilizer incorporation has a direct influence on soil organic matter composition and plant physiological development. Even though the amount of dissolved organic matter in compost is small compared to that in solid organic matter, it still plays a significant role in microbial activity in the soil and in the transport of nutrients, metals and hydrophobic pollutants. Taking into account the important role that dissolved organic matter plays both in the composting process and in the application stages, this research aims to ascertain the assessment of compost stability and its maturity with respect to biochemical and microbiological transformations, which occur in the soluble fraction from the material initially to the final compost [13].

Compost is a product obtained through an aerobic, thermophilic process of decomposition and microbial synthesis of organic substances from residual products, which contains more than 25% relatively stable humus formed predominantly of microbial biomass and which is further subjected to poor decomposition, being sufficient stable so as not to reheat or cause odor or insect breeding problems. The compost resulting from organic waste is richer in nutrients for plants than any artificial fertilizer, being the best natural fertilizer and is produced very easily. The vast majority of organic waste can be submitted to the composting process: vegetable remains (grass, foliage, stems and roots), manure, etc.

Composting means all the microbial, biochemical, chemical and physical transformations that organic, vegetable and animal wastes undergo, from their initial state until they reach different stages of humification, the final product being known as compost.

Compost is the best mulch and natural soil amendment and it can be used instead of mineral fertilizers. But the most important thing is that it is a cheap product. The use of compost leads to the improvement of soil structure, improvement of excessive textures, improvement of aeration and increase of water storage capacity, increases soil fertility and stimulates the development of a healthy root system of plants. The organic matter applied through compost provides food for microorganisms, which keep the soil in healthy conditions.

**Methods used for composting organic waste**

Various technologies (methods) are known for composting organic waste, including manure.

***Traditional composting***

The method has been known since ancient times by farmers who used manure to improve soil fertility [15].

Various technologies can be used in the traditional composting process:

- composting of manure with stratum in which special plots are used for fermentation on which piles of animal droppings are placed, which are covered with soil. The amount of soil should not exceed 15-20% of the weight of the manure;
- composting manure without stratum with alluvial soil. This technology initially provides for the study of the alluvial soil, then the land is chosen (located in a valley) with dimensions of 10 m×100 m, where the composting will take place;
- composting the solid fraction of manure without stratum with plant and soil residues. This compost can be obtained wherever plant residues are found (old straw, fibrous fodder residues). Initially, the land is prepared with an area of 25-30 m$^2$, which is leveled, plowed to a depth of 23-30 cm and then processed with discs. Plant remains are placed on this territory (2% of the weight of the solid fraction of the manure intended for composting) which is compacted. The weight of the soil used to cover the manure pile should not exceed 15% of the weight of the manure prepared for composting:
- composting the solid fraction of manure without stratum with old manure, depends on the shape and size of the pile prepared for composting. Composting begins with throwing the old manure over the solid fraction of the manure without litter, and then the whole mass of manure prepared for composting. In winter, the composting of these two components is carried out without adding soil;
- the production of compost for protected spaces (greenhouses) is carried out near the farms on lands cultivated with perennial grasses in their third year of cultivation, in spring and summer using the mixture of liquid manure, its solid fraction (30%) and alluvial soil (70 %);
- the composting of bird droppings with stratum is carried out similarly to the composting of cattle manure, being covered with a layer of soil.

Liquid poultry manure can be stored in concrete tanks, or incorporated into the soil with autumn plowing or during autumn cultivation [15].

Thus, traditional composting can be used in any type of household to transform animal droppings into organic fertilizer.

***Worm cultivation for the bioconversion of organic waste***

Another method used for the bioconversion of organic waste and obtaining compost is worm cultivation [1], [4], [5], [12]. This method provides for the use as a bio-transformer of organic waste and various species of earthworms (Photos 1 and 2).

Photo 1. The local earthworms of garbage
Source: Own from the internet.

All types of manure, which have been previously subjected to fermentation for various periods of time, can be processed using the technology of bioconversion of organic waste through worm cultivation [8]. Worm cultivation opens new perspectives and possibilities for the management of organic waste from the zootechnical sector in order to obtain valuable organic fertilizer, protein not only for fodder, but also for food, which can become the basis for the production of ecological products [9].

Photo 2. Earthworm Red Hybrid of California
Source: Own photo.

The complex of eco-biotechnologies that are used to maintain the ecological situation of the environment differ according to their degree of effectiveness. They can also include "living technologies", which are used for the purpose of bioconversion of organic waste obtained in various branches of the national economy.

The development of the technology of bioconversion of organic waste through worm cultivation begins directly with the organization of households for worm cultivation. When organizing these households, some conditions related to the objectives and tasks that are placed before the household must be taken into consideration. It is necessary to determine which will be the dominant directions:

1. Increase in the earthworm population.
2. Producing worm compost for marketing.
3. Producing worm compost for personal needs.
4. The production of biological mass to be used in the food ration of animals, fish, birds and in other fields.

For the organization of households for worm cultivation, it is necessary to determine the place from where the organic waste will be collected, which will be the transport routes and the water sources used.

Worm cultivation technology can be practiced indoors and outdoors. No special capital investments are required for the development of indoor worm cultivation technology, but the remaining buildings on the territory of farms and zootechnical complexes can be used. In rooms, worm cultivation is carried out on concrete surfaces where sections are set up and on racks, using wooden or metal crates. It is necessary to mention that the practice of worm cultivation technology indoors is more effective than outdoors, because twice as much worm compost can be obtained here. In the absence of rooms, the organization of the household for worm cultivation can be carried out according to the scheme, which provides for its location in open-air territories, where the worm culture is placed in the substrate from ditches or piles and the technological process takes place from April to October (in the climatic conditions of Republic of Moldova). This scheme is accessible and its use allows the technique to be widely used. On designing the household for worm cultivation, it is necessary to take into account its profile (obtaining of worm compost or worm culture) [14]. Based on this, calculations are made regarding the number of sections and the area occupied by the household for worm cultivation.

In the first year of work, regarding the organization of the household for worm cultivation, it is foreseen to accumulate the necessary amount of earthworms. For this purpose, from 4,000 to 20,000 earthworms are placed in a section (2 $m^2$), resulting in only 200-300 kg of worm compost [4], [5].

The work on the complete cycle in the technology of worm cultivation starts from the second year, if in the previous year the required amount of earthworms was obtained. During this period, the livestock farm switches to the complete worm composting regime, when 30,000 to 10,0000 earthworms must be placed in each section. As a result of the processing of organic waste from a section, 1,000-1,200 kg of worm compost are obtained. The territory intended for the household for worm cultivation is divided into four production sectors. The first sector (for fermentation) is used for organic waste storage, fermentation and compost preparation. The sector is located on a previously prepared surface, where the basic technological process takes place in piles, after the compost is transported to the second production sector (for worm composting). Here, under the influence of worm culture, the compost is processed and transformed into raw worm compost. The raw worm compost is transported to the third production sector, where the preparation of the worm compost takes place (dislodging and drying). From here, the worm compost is transported to the fourth production sector (finished production sector), where the quality of the fertilizer is determined. In this sector the worm compost is screened, sorted into different fractions, packaged, stored and prepared for sale or incorporation into the soil. The nutrient substrate has a double importance for worm culture, serving as a means of food and livelihood, thanks to which the optimal level of life of earthworms is ensured and maintained. Of particular importance for earthworms is the structure of the nutrient substrate and its chemical composition. The substrate must be homogeneous, loose and moist.

Worm cultivation presents a set of activities (stages), the correctness of which ensures the success of the entire technological process.

The main stages of the bioconversion technology of organic waste through worm cultivation are: the selection and preparation of the land in order to organize the sectors and sections for worm cultivation; preparation of the nutrient substrate; placing the worm culture in the nutrient substrate; selection (separation) of earthworms from the nutrient substrate and their preservation.

In households for worm cultivation, sectors with a width of one meter and a length of 50 m are recommended, practicing sector-pairs. The distance between 2 sectors can be 1 m, and between pairs - 4.0 m - 4.5 m. Each sector is divided into sections with dimensions of 1.0 m × 2.0 m. If trenches are used for worm cultivation, then their depth must be 0.5 m - 0.6 m, and if the sectors are practiced in the form of piles, their thickness must not exceed 0.4 m - 0.6 m. In practice, changes can be made in the structure of sectors for worm cultivation (Photo 3).

Photo 3. Modified sectors for worm culture
Source: Own photo.

In peasant households, where the amount of manure is not sufficient for the formation of sectors, for the purpose of efficient use of worm culture, earthworms can be placed in pits with dimensions of 1.0 m × 2.0 m, with a depth of 0.5-0.6 m or piles formed from organic waste of various origins. The bottom of the pit or the land for worm cultivation must be well tamped. The walls of the pit must be covered with planks or other material, to prevent earthworms from leaving the substrate. Heaps of organic wastes are placed on compacted lands. The technology of bioconversion of organic waste through worm cultivation solves the following problems in the sustainable development of agriculture: complete processing of organic waste; revitalization and improvement of soils; obtaining the ecological organic fertilizer with long action; increasing the yield and production of agricultural crops; protection of plants from diseases; environmental protection. The technology of bioconversion of organic waste through worm cultivation is proposed to each agricultural unit, land owners, animal owners, amateur farmers, etc., as an effective method in ensuring the sustainable development of agriculture.

***The use of effective microorganisms for composting organic waste***

Another method used in composting organic waste of various origins is the method of using effective microorganisms. This is a contemporary, relatively young technology, but it is a globally recognized branch of science. For the first time, at the international level, the term "Effective Microorganisms" began to be used in 1986. Later this term is permanently used for the specific technology -

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the Technology of Effective Microorganisms) [2], [6].

Photo 4a. Effective Microorganisms
Source: Own from the internet.

Photo 4b. Colonies of Effective Microorganisms
Source: Own photo.

Effective Microorganisms are an ecological alternative with sustainable benefits for humans, animals and the environment. These are the little helpers in the work in the garden, household, agriculture, ponds and comfort, with the most diverse areas of use (Photo 4a and 4b). The use of Effective Microorganisms (EM) in agriculture opens up new perspectives. EM presents a wide spectrum of use both for businesses dedicated to organic agriculture and for those dealing with conventional agriculture. Efficient Microorganisms favour the vital capacities of nature, acting especially at the aerobic and anaerobic level of soil and plants.

These Efficient Microorganisms (EM) technology is a creative science always in development, which constantly discovers new possibilities of the specific use. Thus, it was found that EM efficiently decompose heavy metal salts.

In SPIBZVM the purpose of the investigations carried out was to evaluate the role of microorganisms of the preparations with EM „Baikal ЭМ-1", „EM-1" and PoultryStar®meEU on the bioconversion process of two types of cattle and poultry manure, with the subsequent study of the quality of the compost obtained and its influence on the physiological development, quality and yield of corn grown on the lots where this compost was incorporated.

The analysis of the obtained results demonstrated that the activity of Effective Microorganisms from preparations „Baikal ЭМ -1" and „EM-1", are manifested more intensively in the first period of underway in the process of bioconversion of the biodegradable organic wastes and influenced beneficially on quality indicators of obtained compost [6]. Preparations with EM are multifunctional, having a wide spectrum of action, due to the groups of microorganisms they contain. The largest groups of EM are: photosynthesis (photosynthetic), lactic (lactic acid bacteria), fungi (yeasts), actinomycetes, fermentation fungi. These groups possess antioxidant, purifying properties and do not contain genetically modified microorganisms, but consist of multiple microorganisms, which are present in the natural environment around the world [2]. The area of use of Effective Microorganisms is vast, it includes both organic and conventional agriculture.

The advantages of using EM Technology are:

- acceleration of the process of humus formation (formation of the clay-humus complex) and relaxation of the soil;
- improving soil quality, which will result in reduced erosion;
- supporting the activity of life in the soil, including the growth of the earthworm population;
- improving soil fertility, saving fertilizers, increasing the soil's heat capacity, which leads to early seed germination, flowering and faster fruit formation;
- obtaining more resistant and vigorous plants;
- obtaining a rich harvest with high quality products;
- reducing costs for fertilizers due to a better availability of nutrients in the soil;
- protecting groundwater from pollution [3], [7].

Compost is the best mulch and natural soil amendment and it can be used instead of mineral fertilizers. But the most important thing is that it is a cheap product. The use of compost leads to the improvement of soil structure, improvement of excessive textures, improvement of aeration and increase of water storage capacity, increases soil fertility and stimulates the development of a healthy root system of plants. The organic matter applied through compost provides food for microorganisms, which keep the soil in healthy conditions. The use of organic waste composting methods in households with diverse ownership solves a number of problems, including: processing organic waste, improving the ecological situation and developing organic agriculture.

## CONCLUSIONS

As a result of the research, it was found that: organic waste composting methods can be used as an effective solution in ensuring ecological agriculture with organic fertilizers and environmental protection;
all composting methods are welcome for agriculture, because they solve complicated environmental problems: complete processing of organic waste, obtaining organic fertilizers and ecological agricultural production, and improving the ecological state of the environment; organic waste management through the use of various composting methods can be proposed to each agricultural unit with various types of property, landowners, animal owners, amateur farmers, etc.

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(c)15.817.05.01.A "Ensuring scientific support for the competitiveness of livestock production by capitalizing on biotechnologies in breeding, nutrition, reproduction and sanitation of autochthonous and imported animals".

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# STUDY ON THE IMPORTANCE OF USING THE GRADING SYSTEM IN WHEAT BLEND QUALITY MANAGEMENT

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***Abstract***

*Cereals production, storage, processing and commercialization have to be done according to the rules and procedures mentioned in The Food Grain Grading Handbook in order to ensure a high quality along the whole process from raw material to final product. The storage of wheat in separate cells, based on the quality indicators mentioned in the Grading Handbook, facilitates the optimal milling blends, in order to obtain the assortment of flour required by bakery processors. In this context, this study aimed to present the importance of using wheat batches, graded according to the wheat grading system, to obtain milling blends in the technological wheat grinding process. Considering the hectoliter weight (kg/hl) indicator used as a benchmark in the grading process, two wheat samples were used: a grade 1 wheat sample (81.3 kg/hl) and a grade 2 wheat sample (75.2 kg/hl). Also, the research highlights the main quality indicators, which are taken into account when putting together milling blends: moisture, wet gluten, falling number, mechanical work. The use of graded wheat samples and the establishment of the proportion of wheat samples in the milling blend through rheological analyzes and baking tests, led to obtaining the type of flour with the intended bread manufacture properties. If it is not applied the grading system, the consequence is that mixing a small amount of lower quality wheat with a higher quality batch, will depreciate the final quality of the milling blend.*

***Key words*: *wheat grading, milling blends, quality indicators***

## INTRODUCTION

Cereals production, storage, processing and trading should be carried out according to the specific rules and procedures destined to ensure quality management along the food chain from raw material to final product.

In this respect, quality standards are the key tool put at the disposal of graders in order to fulfil their tasks.

In Romania, there is the Grading Handbook which contains a set of rules and procedures based on the national standards in force. For food grains, the handbook has been in force since 10 July 2017, as approved by Order 228/2017 of the Ministry of Agriculture and Rural Development (MADR) [12].

The Food Grain Grading Handbook is intended for use as a work instrument for graders. It is based on the classifications and grades established by the National Food Grain Grading System in Romania, and it includes information and work methods that the graders need to apply [5].

The biological properties of wheat play an important role in its procurement process [21]. The market value of wheat grain is determined by various factors such as kernel morphology, texture, test weight, and the shape of the germ [13]. Ponce-García et al [16] note that the physical quality of the kernel plays an important role for identifying the engineering characteristics of cereal crop grains, while [15] point out that studies concerning the relationships between wheat kernel physical properties and milling properties have been carried out since the beginning of the cereal processing industry.

Consequently, the quality of cereals is an essential element of the entire value chain, for the storage of cereal, the processing and, eventually, the provision of finished products to the beneficiary.

The monitoring and batching of the cereal received in the milling units is the first step needed to obtain products having a consistently superior quality [7]. This step is very important for the operations to be applied on raw material wheat, as a very good organization of the wheat according to its quality allows the processing unit to make blends so as to streamline both the production process, and the costs for the raw materials [4], [3].

The storage of wheat according to quality starts with the quantitative and qualitative reception [18].

The grading of food grains is the operation consisting of identifying and separating batches of cereals, pulses, and oleaginous seeds according to their appearance and physical condition or according to one of their special characteristics (SR ISO 5527:2002) Cereals. Terminology).

The grading system groups food grains by quality levels, which reduces transaction costs related to their marketing [17].

The grading system allows to protect the quality and the value of products of very high quality. Any failure to apply the grading operation leads to potential depreciation of the final quality of the product when blending a small quantity of low-quality product with a batch of the same product, but having superior quality [10].

The grading system enables better results of the research dedicated to variety improvement [9].

In this context, the purpose of the paper was to study the importance of using the grading system in wheat blend quality management.

## MATERIALS AND METHODS

The first stage is the obtaining of the representative sample. The sampling is conducted according to the standard SR EN ISO 24333 Cereals and cereal products. Sampling [6]. Two graded wheat samples were used (a wheat grade 1 sample and a wheat grade 2 sample) which led to an optimisation of working time, while facilitating the obtaining of milling batches.

The blend made from the two wheat samples (*Triticum aestivum L.*), of differing qualities was analysed to determine the optimum mix for obtaining flour type 650, which is most often used to make bread. After the samples were pre-cleaned, the mass per hectolitre (SR EN ISO 7971-3/2010) and the moisture (SR ISO 712:0210) were determined for each wheat sample, using the fast analyser Perten 5200-A. This was followed by the milling of the samples, using two laboratory mills, respectively the Perten hammer crusher and the Chopin CD1 roll mill. The milled samples were then analysed to determine moisture using the Sartorius MA 45 Moisture Analyzer, as well as the wet gluten content (SR ISO 21415-2:2008) via the mechanical method, using the Yucebas Glutomatic System. The Falling Number (SR EN ISO 3093:2010) was determined, using Falling Number Yucebas, and also the rheological properties of the dough with the Chopin Alveograph (SR EN ISO 27971/2008). The Farinograph was also used, for the dynamic testing of wheat dough mixing properties, to assess the quality of the wheat and the processing of properties for this dough. The testing procedure is standardized in the international standards [14] (ICC standard 115/1, ISO 5530-1, AACC standard no 54-24) [1]. Kneading is a fundamental operation in bread manufacture technology. Its role is to render dough that is homogenous, cohesive, non-sticky, tenacious, elastic, and expandable. In the kneading process, the proteins are hydrated, the quantity of incorporated water increases, and the dough improves its consistency and acquires elastic qualities [11].

Gluten proteins play the main part in dough formation. In the presence of water, they swell up and, under the influence of the mechanical kneading action, they are joined together and make up the gluten. Its structure resembles a continuous network of protein-based films, which incorporate the starch granules and which lead to obtaining a dough capable of expanding under the pressure of fermenting gases. The gluten formation process is a complex one, and it occurs progressively in the dough [14].

To form the structure characteristic to the dough, intermolecular reactions are necessary. This is possible during kneading, when, as a result of protein hydration and of the energy transferred to the dough, the bonds conditioning the globular shape are broken.

In properly kneaded, high-quality dough, the protein film is homogenous and uniformly distributed around the starch granules [2].
The intensive kneading is characterized by a vigorous kneading of the dough, achieved at high rotative speed of the kneading arms. Such intensive kneading is aimed at increasing the number of sulfhydryl groups in the gluten proteins, which are capable of interacting with the intramolecular disulphide bonds. Thus, a network of gluten fibres is formed, having extremely fine openings, with high tensile strength [8].
After the mixing time ends, the dough is taken out of the mixer, it is let to rest for 5 minutes, and afterwards it is divided. The 45 minutes spent in the dough proofer are followed by the 15 minutes of baking time at 220°C in an electric oven.

## RESULTS AND DISCUSSIONS

Table 1 indicates the results of wheat sample analyses. Samples 1(from wheat grade 2) and 2 (from wheat grade 1) are the initial samples, and the sample named *"wheat blend"* is a blend made up of 60% sample 1 wheat and 40% sample 2 wheat.

Table 1. Wheat sample quality indicators

| Quality indicators for wheat | Wheat sample 1 (wheat grade 2) | Wheat sample 2(wheat grade 1) | Wheat blend |
|---|---|---|---|
| Moisture, (%) | 12.3 | 11.3 | 11.8 |
| Wet gluten, (%) | 22.5 | 32.5 | 26.4 |
| FN | 435 | 458 | 450 |
| W (J) | 119 | 341 | 210 |
| P/L | 1.54 | 0.57 | 1.1 |
| Mass per hectolitre, (kg/hl) | 75.2 | 81.3 | 78.8 |

Source: original results.

The blend was selected according to Table 2, which contains the quality indicators of the two wheat samples. This table substitutes the standard calculation method for obtaining the milling batches. It is a much faster system, allowing for the identification of an accurate percentage. First the analyses for the wheat batches intended for use in production are input and, using the entered formulas, the appropriate parameters are selected to obtain the desired flour.

Table 2. Average analysis of wheat blend

| Cell | Wheat sample 1(wheat grade 2) | Wheat sample 2(wheat grade 1) | Average analysis |
|---|---|---|---|
| Blending ratio (%) | **60** | **40** | **100** |
| Wet gluten, (%) | 22.5 | 32.5 | 26.5 |
| G index (%) | 97 | 75 | 88.2 |
| FN | 435 | 458 | 444.2 |
| P | 71 | 88 | 77.8 |
| L | 46 | 115 | 73.6 |
| G | 15.1 | 27.6 | 20.1 |
| W (J) | 119 | 341 | 207.8 |
| P/L | 1.54 | 0.57 | 1,152 |
| Ie | 39.5 | 50 | 43.7 |

Source: original results.

According to Figure 1, upon analysing the most important parameters of the wheat samples (wet gluten, flour strength - W, mass per hectolitre), it can be noted that the 60/40 ratio is accurate, as the resulting parameters can be found mid-way between the values of the two samples from which the wheat blend was made, and the minimum quality requirements for milling are met.

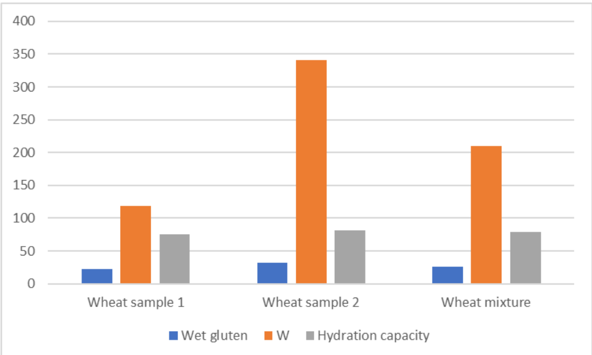


Fig. 1. Quality indicators determining the optimum make-up of the wheat blend
Source: original results.

Three flours obtained have no variation in colour or appearance, according to the ash content in Table 3.

Table 3. Quality indicators of flours obtained from the wheat samples

| Quality indicators for flour | Flour from wheat sample 1 | Flour from wheat sample 2 | Flour from wheat blend |
|---|---|---|---|
| Moisture | 14.4 | 13.8 | 14.3 |
| Wet gluten | 24 | 33.6 | 27.8 |
| FN | 378 | 418 | 395 |
| W | 137 | 304 | 245 |
| P/L | 1.17 | 0.85 | 1.37 |
| CH | 52.5 | 62.8 | 61.5 |
| Stability | 5.32 | 9.42 | 7.49 |
| Resistance (135 min) | 404 | 744 | 614 |
| Extensibility (135 min) | 2.33 | 6.46 | 3.23 |
| Ash | 0.67 | 0.63 | 0.65 |

Source: original results.

Quality indicators determining the optimum composition of flours obtained from the wheat samples are shown in Fig. 2.

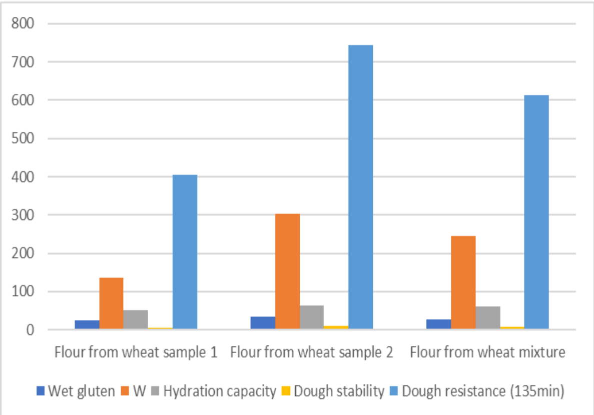


Fig. 2. Quality indicators determining the optimum composition of flours obtained from the wheat samples
Source: original.

The physical and chemical testing of the samples was followed by the baking test for each flour type. The recipe presented in Table 4 was used.

Table 4. Recipe for bread obtained from the wheat blend

| Bread recipe | Investigational flour test/kg |
|---|---|
| Flour | 100 |
| Yeast | 2.4 |
| Salt | 1.8 |
| Water | 55 |

Source: original.

This dough has a sticky consistency, with a shiny appearance, high extensibility, the dough gives very easily, and it is hard to process.

The wheat from the sample 2 flour has a very cohesive, strong consistency, it is very hard to process, the dough resists processing, and breakage effects occur on its surface.

The dough using the blend of the two wheat samples is a cohesive dough, with a smooth appearance, easily extensible, it does not resist processing, it improves its tenacity and gas retention capacity, it is highly tolerant upon proofing.

After the 45 minutes spent in the dough proofer, we can notice the behaviour of the dough by looking at the slit and the behaviour of the dough [19],[20]: in the case of the wheat flour originating from wheat sample 1, the slit is not straight, it is not sufficiently proofed, and in the case of the dough made from sample 2 wheat flour, we can note slight over fermentation and, upon slitting it, the knife sticks to the dough and it rendered the slitting difficult.

In the case of the dough obtained from the wheat blend flour, we noted proper proofing, the knife moved easily upon slitting, with no sticking marks.

Photo 1. Section in the bread obtained from wheat sample 1
Source: original.

The bread obtained from the flour milled from wheat sample 1 is a bread having poor volume, it is flattened, it seems slightly sodden, its surface is whitish, the core has small dense pores. The height of the bread is just at 6 cm, and its width is of approximately 10 cm (Photo 1).

The bread obtained from the milled flour of wheat sample 2 seems to be a bread that was forced to proof, it broke on the edges, and the colour of the crust is dark brown in patches, the core has non-uniform pores.

The part that was in contact with the tray is packed and the phenomenon called "bottom crust" was created. The height of the bread is 7.3 cm, the width is 9 cm (Photo 2).

Photo 2. Section in the bread obtained from wheat sample 2
Source: original.

The bread obtained using the flour milled from the wheat blend 60% wheat 1 and 40% wheat 2 is one that has a uniformly baked crust, a core with non-uniform, but loose pores (Photo 3).

Photo 3. Section in the bread obtained from the blended wheat sample
Source/original

## CONCLUSIONS

The grading of wheat as a raw material is an essential instrument in determining purchase price. The application of the grading system included in the Grading Handbook is a guarantee of the fact that the manufacturers will obtain a fair price for their product, according to its quality. Thus, the manufacturers will be encouraged both in terms of yield, and in terms of quality. The application of the grading system secures the constant quality of the stored food grains, sustaining internal and international transactions.

The grading system allows silo managers and transporters to organize the storage system for food grains in a more efficient manner. It improves the manufacturing/sales costs ratio and the price of food grains.

The preliminary tests performed on wheat in the laboratory provide clear and accurate information on its quality and they facilitate the storage/batching process.

The determination of moisture in the raw material is one of the key factors for establishing how it is stored.

The quantity and quality of moist gluten provide clear information on the properties of the intermediate product, namely the dough.

The hydration capacity is directly influenced by the grinding grade and the quality of the flour gluten, providing clear information on the stability of the intermediate product, the dough, in the manufacturing process.

The determination of mechanical work helps the milling facility classify the wheat so that it may be stored according to its quality, so that the flour milled from the respective wheat to be of good quality;

The baking test is the key element that accurately indicates the behaviour of the flour during the technological process. A flour type may have the same physical and chemical parameters, but a completely different behaviour in the dough.

The storage of wheat in batches, according to its grade, leads to an optimisation of working time, of the available storage area, while facilitating the obtaining of milling batches. The importance of milling batches consists of the fact that a product of uniform quality is obtained, and this has a positive influence on the clients' perception regarding the finished product.

The analysis of the blends clearly highlighted the importance of milling batches for obtaining flour of target quality for the finished product.

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# RESEARCH ON THE CHEMICAL AND BIOACTIVE EVALUATION OF ORGANIC PUMPKIN PULP (*CUCURBITA MAXIMA*)

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***Abstract***

*A vegetable with a high nutritional value and with a low cost of cultivation makes the pumpkin a coveted candidate as a functional ingredient in obtaining bakery products with a special destination. The aim of the work was to carry out a study on the introduction of pumpkin flesh (Cucurbita maxima), obtained in an ecological system, in the production of gluten-free products intended for people with metabolic or allergic problems. Fresh and baked pumpkin pulp was analyzed from a chemical and biochemical point of view. The demand for vegetable ingredients that add value to a food product has increased a lot recently. Also, the demand for bakery products is increasing, especially for products specific to a certain segment of vulnerable consumers. The obtained results showed that protein content for Cucurbita maxima pumpkin flesh is 23.06% for the fresh version and 15.51% for the baked version; and the fiber content of the analyzed samples is 10.794% for the pumpkin pulp and 7.623% for the baked pumpkin pulp. Regarding total phenolic, values of phenolic compounds found in our research, are 36.03 mg/100g for pumpkin flesh and 40.40mg/100g for pumpkin flesh. A high of value total phenolic compounds will have a major impact on bakery products.*

***Key words***: *pumpkin, carotenoids, polyphenolic compounds*

## INTRODUCTION

The current conjuncture determines a new approach to the choice of ingredients and the creation of new formulas for food products in the bakery industry. Such as, the accelerated increase in the price of animal ingredients, the new food and environmental policy of the European Union, as well as the emphasis placed on ecological and sustainable products, determine the change in the optics of producers in this field. In order for the processing units to survive, they must find solutions to replace conventional raw materials with other ingredients that are much more accessible, sustainable, sustainable and nutritious. For this reason, the use of vegetables and fruits in the bakery industry becomes a practice that will determine a new breath in the creation of new assortments and the production of products on a large scale for people with various metabolic conditions. Vegetable ingredients are important sources of fibers and valuable nutrients for the human body.

In the last 30 years, many vegetables lost their economic importance. The main causes being the reduction of the lots put into use, but especially the drought and temperature differences that created special problems for the producers. Due to the drought, imports were stimulated, which in turn caused imbalances in the activity of small entrepreneurs.

A culture that was forgotten at the expense of imported products was the pumpkin culture. Pumpkins are the genus *Cucurbita* and the family *Cucurbitaceae*. The pumpkin species available include *C. maxima* (called "bostan" or “winter pumpkin” in Romania), *C. moschata* (called "plăcintar" in Romania) and

*C. pepo* (called "dovlecel" in Romania). These three species are cultivated worldwide and have high production yields [28]. In the current selection of pumpkins in Romania, only a few crops from the species *Cucurbita maxima* L, *Cucurbita moschata* Duch are included. In 2020, Romania had a production of 21,470 tons/year according to [11].

In this context, the research regarding the reintroduction of this species into culture has a very solid motivation, especially in ecological culture.

Pumpkins are cooked and consumed in many ways, and most parts of the pumpkin are edible, from the fleshy shell to the seeds. Pumpkin flesh is consumed in soups, puree, smoothies and juices, or it is incorporated into various foods, such as gluten-free cakes, candies, breads and pastry products. In the many country, pumpkin is a must have by Halloween or in different dishes, especially in the autumn season. Pumpkin seeds and pumpkin seed oil are also commonly consumed in some countries.

Taking into account the prospects of introduction and expansion in the culture of many cucurbit species, new and much more diversified crops can be obtained considering the adaptability of the species to the environmental conditions and the type of soil specific to the area. Due to its high resistance to diseases and pests, it is a species that can be successfully cultivated in an ecological system.

Since it is not sufficiently exploited, we proposed a more thorough study of the *Cucurbita Maxima* species known as Pumpkin, and its valorization by obtaining different products with high nutritional and economic value. Pumpkin is an edible food which must to be included in daily diet because can give various health and therapeutic benefits in our body. Many research studies have been conducted on the bioactive ingredients of pumpkin peel, flesh, and seeds to provide an overall picture of their health-related impacts, which have demonstrated its anti-inflammatory [25], antibacterial, anticarcinogenic [13], antidiabetic [8], and antihypertensive properties, associated with this climber for diabetes [4, 23].

In food industry, pumpkin has attracted increasing attention in special for its nutritional profile, and due to the fact that it can be included in a wide range of recipes. The most important edible parts of the pumpkin are: *pumpkin seeds* - are rich in fiber, protein, and unsaturated fatty acids, which can all play a supportive role in healthy weight loss, and the edible oil obtained from the pumpkin seed is rich in oleic acid; *pumpkin pulp*: the ripe fruit is sweet and used to make confectionery-pastry-bakery and juice or slightly alcoholic beverages. Pumpkin pulp is used in the food industry for the production of pastries, baked goods, juices, jams, marinades, and baby food.

Pumpkin culture is profitable because it does not require high care expenses and they have a good yield per crop. At maturity, pumpkin are stable for 1–3 months after their harvest, after they become susceptible to microbial spoilage, moisture loss, and color changes after peeling. Thus, to extend the shelf life, pumpkin pulp is subjected to drying and branding techniques to obtain pumpkin flour, extremely versatile flour often used to obtain functional foods. Other preservation methods applied are: freezing, baking, preservation in the form of puree. This also allows pumpkin to be used as an ingredient in manufacturing foods such as bakery-pastry products for quality addition [30], as the rich nutrient content of this vegetable increases the nutritional quality of baked products [17].

Pumpkin inserted in cookies or muffins recipe, have been found to bring good nutritional value and sensory characteristics who make them acceptable and well-appreciated to consumers [31].

Pumpkin is rich in carotenoids, polysaccharides, oils, sterols, para amino benzoic acid and good amount of vitamins and minerals. Pumpkin seeds are of high protein, low in fat content and they are good source of elements like potassium, magnesium, copper, zinc, selenium and molybdenum. The phyto-constituents of pumpkin make it vital in different types of diet. Pumpkin is the best-known sources of beta carotene. Beta-carotene is a powerful antioxidant that gives orange vegetables and fruits their vibrant color. The body converts any ingested beta carotene into vitamin A. All these benefits made it essential to include in our daily diet. Large size of fruit is a major limitation; to overcome this many processing methods like drying or dehydration are applied to make flour [2].

In this context, the purpose of the paper was to carry out a study on the introduction of pumpkin flesh (*Cucurbita maxima*) in the production of gluten-free products intended for people with metabolic problems or allergies.

## MATERIALS AND METHODS

The raw material used was purchased from Bio&Co. The pumpkin was selected based on soundness, cleanliness, no pest damage or mechanical damage.

Fresh and baked pumpkin pulp was analyzed from a chemical and biochemical point of view.

The demand for bakery products is increasing especially for products with specificity for a certain vulnerable consumer segment. To meet the sensory and nutritional expectations of customers, these cookies are developed and standardized.

*Plant material and pulp preparation*: the pumpkin fruits were washed, halve, peels and seeds was removed. The peeled pumpkin was cut into small cubes and prepared as follows: *pumpkin flesh* it was grated and *pumpkin flesh baked* at 200°C/40 minutes in a convection oven. The samples were evaluated in triplicate for each analysis.

Methods of sample preparation and chemical analyses it was carried out at the laboratories of Research Center for Studies of Food Quality Q-lab, University of Agronomic Sciences and Veterinary Medicine of Bucharest, Romania.

*Determination of the dry matter (DM)* was achieved by weighing 1 g of the sample, and then dries at 105°C, in an oven until a constant weight. The determination of the dry matter content (DM) was carried out by the gravimetric method, through the removal of water by evaporation and weighing, according to the European Pharmacopoeia, edition 7, the results being expressed in percentages.

*Elemental analysis C, H, N and determination of protein content*- The analysis of the total N, H, C content was realized on the Dumas method, using the Elemental Analyzer EA 3000. This method involves the total combustion of the sample in atmosphere of oxygen. The gases produced are reduce with the help of copper to $H_2O$, $N_2$, $CO_2$ and $SO_2$ and quantified using a universal detector. From the ground samples was weighed of 2–3 mg, enter in a tin crucible and subjected to combustion at 950°C. The amount of protein was calculated by multiplying the total nitrogen content by a factor of 6.25.

*Determination and quantification of fibers by the Acid detergent fiber (ADF) method according to Van Soest* - the samples were dried and ground to pass through a 1mm sieve. Weigh in a crucible 1 g of grinded sample and add 100 ml of acid detergent solution at room temperature and some drops of n-octanol. Heat, then leave to reflux for 60 minutes from the moment the sample reached boiling point. Filter and wash 3 times with boiling water, then twice with cold acetone. Dry 8 hours at 105°C and let cool in a desiccator, and after this is weighing.

A calculation is:

ADF = {[(crucible weight + residue weight) - crucible weight]/ Sample Weight} x 100; [%].

*Determination of total polyphenol content (TPC) by Folin-Ciocâlteu method* - Depending on the type of sample, 1 g of material is mortared in the presence of quartz sand and 10 ml of 70% methanolic solution in water. The extracted sample is left overnight in the dark at room temperature. The next day, shake for 60 minutes to favor the extraction, centrifuge for 5 minutes at 5,000 rpm and 4°C and transfer the supernatant to another bottle. Over the remaining sediment, add another 10ml of 70% methanolic solution, shake and centrifuge. Repeat procedure. Finally, the 3 supernatants are combined, the final volume of the extract being 30 ml. For the quantitative determination of the total content of polyphenols, the Folin-Ciocâlteu method following a protocol adapted from [12].

*Determination of the content of carotenoid pigments by UV-VIS* The carotenoids pigments content was quantified after petroleum ether extraction method. In a mortar with pestle, 1 g of the sample was mortared in the presence of quartz sand, and washed quantitatively several times with petroleum ether.

The ethereal extract was vacuum filtered and transferred quantitatively into a 50 ml volumetric flask. It was dosed spectrophotometrically against a petroleum ether blank at wavelengths 452 and 472 nm, using the Specord 210 Plus UV/VIS spectrophotometer. Results were calculated according to the formulas proposed by [30]. The results obtained and presented are the average of three independent values and are expressed as mean ± standard deviation (SD).

*The determination of the antioxidant activity by the DPPH method* consists in establishing the antioxidant activity based on the DPPH test, using the stable free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH), according to the method described by [9]. To determine the antioxidant activity, a volume of 200 µl of the extract solution obtained for polyphenols is used, and 2 ml of DPPH solution (0.2 M) in methanol is added. Stir magnetically in the dark for 30 minutes. After incubation, the absorbance is measured at a wavelength of 515 nm.

*Statistical analysis* of obtained data was performed using Microsoft Excel for standard deviation and represent the average of three replicates with independent sample preparation.

## RESULTS AND DISCUSSIONS

### Overview

Pumpkin cultivation was carried out in Niculești commune, Ciocănari village, Dâmbovița county within Bio&Co, an ecological vegetable farm, which is a project of *Ateliere Fără Frontiere (Workshops without frontiers)*, a Romanian non-profit association that creates jobs for vulnerable people, in workshops of social and solidarity economy.

To facilitate the access of people from vulnerable backgrounds to the labor market, in order to build their self-confidence, professional and personal independence.

The climate in the area is temperate continental with hot and dry summers and cold winters, dominated by the frequent presence of cold continental air masses from the East, or Arctic from the North and strong winds that blow snow. The multiannual average value of the air temperature is 11°C, a value that is characteristic of the eastern sector of the Romanian Plain. The multiannual average amount of precipitation oscillates around 500 mm. The wind regime is characterized by prevailing air currents from the Northeast and East, currents that can reach 125 km/hour in winter. The land on which the town is located was part of *Codrii Vlăsiei*.

### Research data

*Pumpkin culture*

Pumpkin grows well in most types of soil, whether light, medium or heavy, as long as they are well drained.

Due to the fact that it is an ecological crop, before the establishment of the crop, an agrochemical mapping of the land was carried out.

Mapping was carried out before and after basic fertilization with manure. Before the establishment of the crop on this land there was an alfalfa crop that was incorporated into the soil in the fall with the plowing (Table 1).

The material incorporated as biodegradable fertilizer - Lucerne (*Medicago sativa*) is a perennial plant from the legume family, with leaves composed of three leaflets and blue-violet flowers, cultivated as a forage plant. Research shows that, while following the application of chemical fertilizers with nitrogen, plants can transform only 50% of the administered amount into plant matter, the nitrogen left in the soil after a leguminous crop is fully utilized.

Table 1. Agrochemical characteristics of the land on which the experience was located

| Emplacement | pH | Soluble salts, [%] | Content of soluble forms [ppm] | | | |
|---|---|---|---|---|---|---|
| | | | $N-NH_4^+$ | $N-NO_3^-$ | $P-PO_4^{3-}$ | $K^+$ |
| Before fertilization with manure | 6.71 | 0.054 | 14.25 | 19.72 | 11.43 | 55.00 |
| After fertilization with manure | 6.64 | 0.050 | 47.50 | 152.86 | 28.57 | 165.00 |

Source: [27, 35].

It is estimated that after an alfalfa crop, average 280 kg nitrogen/ha. The green leaves of this plant contain eight essential amino acids (which the body is unable to synthesize). *Medicago sativa* distinguished by the high content in enzymes, phytoestrogen, protein, calcium, iron, magnesium, phosphorus, potassium, essential amino acids and vitamins C, B6, D, A, K and E (biologist Frank Bouer) [15].

Alfalfa was present on the plot used in the experiment for 3 years, and then it was incorporated into the plot by plowing after the last mowing. In autumn, 10 t/ha of manure was also administered. The manure was very well decomposed. After applying the manure, a deep plowing of the land was performed. From the data of table 1, it is observed that the soil pH varied between 6.71 before fertilization and decreasing to 6.64 following the application of manure. Nitrogen in the soil, as well as the level of phosphorus and potassium, also increased a lot. The level of nutrients is balanced, the soil being well-supplied for a pumpkin crop, and during the vegetation period, three more facial fertilizations will be applied. In the spring, the land was shredded with the disc harrow and the leveling bar, and the day before sowing, it was once again passed with the combiner to achieve a good compaction of the soil and maintain its moisture to ensure the rapid emergence of the seeds.

The establishment of the culture was done by sowing directly in the field respecting the sowing distances from the experimental scheme.

Sowing was done on April 30, 2021, when the soil temperature reached 9-10°C, it was sown at a depth of 3-4 cm and 3 seeds were placed in each nest. The seeds were purchased in Austria and are certified organic.

*Care work carried out in culture*

Weed control by mechanical weeding when the plants were small, then hand weeding done very carefully so as not to displace the pumpkin seeds.

After the pumpkin plants grow, they cover the ground very well and smother the weeds themselves. Irrigation was carried out at the nest when the plants were small, then the culture was no longer irrigated.

No disease and pest attacks were reported in the crop considering that this crop was sown for the first time on this land and there are no pumpkin crops in the area.

In ecological crops, monoculture is not recommended because the pumpkin can have diseases such as powdery mildew and downy mildew, and the remains of stems can become a source of infection, causing damage to seedlings and developed plants. Consequently, on the same plot, the pumpkin can be cultivated again only in the third year.

*Sources of raw material and preparation*

The raw materials used were purchased from Bio&Co. For current use as an ingredient, it was selected only healthy, solid, intact pumpkins without mechanical damage or pests. The pumpkin was washed, halve, peels and seeds was removed. The peeled pumpkin was cut into small cubes and prepared as follows: *pumpkin flesh it was grated* and *pumpkin flesh baked* at 200°C/40 minutes, in a convection oven. The samples were evaluated in triplicate for each analysis.

*Evaluation of physical properties*

Pumpkin flesh is a good source of dietary fiber, which plays very important role in human health. Because of low energy value dietary fiber obtained from pumpkin pulp is very helpful in lowering blood glucose level [16, 33].

Extracts of pumpkin pulp exhibited antimicrobial and antioxidant potential [6]. Extracts of pumpkin, enriched with carotenoids can be called as phyto-complex, a good source of bioactive compounds, delays cell proliferation in a human chronic lymphocytic leukemia cell line [22, 5].

Table 2. Proximate composition of fresh pumpkin

| Products | DM % | Protein % | ADF (Acid Detergent Fiber) % |
|---|---|---|---|
| *C. maxima* fresh | 5.676 ± 0.055 | 23.06 ± 0.787 | 10.794±0.570 |
| *C. maxima* baked | 10.046 ± 0.098 | 15.51 ± 4.130 | 7.623±0.219 |

Values are given as means of three replicates ± SD. Means with different superscript letters within a column are significantly different ($P < 0.05$). SD = Standard deviation of the mean
Source: Determinations made through the EcoDonela project.

It is known that the chemical composition of the pumpkin can vary greatly depending on the climatic conditions of that year and genetic factors.
After the analysis, it was found that the humidity of the fresh sample is 96.42%, a value that approaches the results obtained in other studies. For example, in other bibliographic sources, the humidity of fresh pumpkin is between 89.50-95.00% [36]. We can say that our sample is in parameters. The humidity of the sample of baked pumpkin is about average 90%, a rather high value, but it is justified by the use of mild heat treatment, so as to protect its bioactive components. We can conclude that the fresh *Cucurbita maxima* pumpkin has a higher humidity, which leads to obtaining soft, fluid doughs, something found in work practice. These problems influence the long-term storage and preservation. *Cucurbita maxima* pumpkin flesh baked at 200°C/40 minutes in the convection oven has a greater stability in the product, but the still high humidity creates the same problems as with the fresh one. Pumpkin flesh baked by *Cucurbita maxima*, has good stability in mixtures and integrates nicely into the finished product. Due to the lower humidity, the doughs are more consistent, aromatic and beautifully colored.
One of the most important chemical content quality indicators is the dry matter content. It ensures the quality and output of the recycled products. Regarding the content of dry matter, the results show (Table 2) that in the case of fresh *Cucurbita* pumpkin flesh, a maximum value of 5.676 % and by baking it increases to approximately 10.046 %. The fruits of great pumpkins accumulate higher amounts of dry matter compared with the amount of the fruits of oil pumpkins. This is due to the relatively high sugar content in the flesh of *Cucurbita maxima* fruits.
Protein is important for tissue repair and cell growth, being involved in building each tissue in human body. They affect transport through the cell membranes of various vitamins and minerals. The protein content for *Cucurbita maxima* pumpkin flesh is 23.06 % for the fresh version and 15.51 % for the baked version.
The fiber content of the analyzed samples is 10.794% for the pumpkin pulp and 7.623% for the baked pumpkin pulp. These values are confirmed by similar studies, respectively values of 6.66% of the dry substance. The reduced values of the fiber content in the case of the cooked pulp is confirmed by the literature reports that mention that blanching reduces the amounts of starch, ash, fiber, phosphorus and iron due to leakage during the blanching process [14, 19, 10]. Presence of dietary fibers in pumpkin pulp, reduce sugar levels increased with increasing substitution of pumpkin flesh or flour in bread.
*Determination of biological activity*
Bioactive compounds, important for human nutrition, are considered an excellent alternative for disease prevention and treatment. These compounds are beneficial for health, because they strengthen the immune system and prevent the body from getting sick. We can mention the most important bioactive compounds present in pumpkin: polyphenols, carotenoids, vitamins, omega-3 fatty acids, organic acids, nucleosides and nucleotides, and phytosterols have attracted a lot of attention due to their role in preventing several chronic diseases. The scientific world is continuously searching for natural sources

of bioactive compounds, and many have found pumpkin (Cucurbita L. spp.) extremely interesting because it contains large amounts of bioactive compounds [20]. Due to the high content of carotenoid compounds, pumpkin (C. maxima) pulp is a rich source of natural antioxidants, especially β-carotene.

Antioxidants are compounds that can reduce oxidative stress directly, reacting with free radicals, or indirectly, inhibiting the activity or expression of free radicals through intracellular enzymes. There are two types of antioxidants: the body's own antioxidants (glutathione, coenzyme Q, alpha lipoic acid) and the antioxidants taken from the diet (vitamin C, vitamin E, selenium, beta-carotene) which are well represented in colourful fruits and vegetables: beets, carrots, spinach, broccoli, tomatoes, cherries, red grapes, berries. Today, there is a growing interest in plants such as ginseng, turmeric, ginkgo, rosemary, green tea, garlic, ginger, which are rich in antioxidants.

Table 3. Proximate composition of fresh pumpkin

| **Type of pumpkin flesh** | **Total polyphenol content (TPC) (mg / 100 g)** | **Antioxidant activity (mg equiv Trolox/100 g)** | **Content of carotenoid pigments (mg/100 g)** |
|---|---|---|---|
| *C. maxima* fresh | 36.03 ±5.27 | 1.746 ± 0.225 | 0.776 ± 0.019 |
| *C. maxima* baked | 40.40 ±4.31 | 1.751 ± 0.183 | 2.388 ± 0.120 |

Values are given as means of three replicates ± SD. Means with different superscript letters within a column are significantly different ($P < 0.05$). SD = Standard deviation of the mean

Source: Determinations made through the EcoDonela project.

Phenolic content they have an important role in the growth and reproduction of plants, and contribute to the color and sensory characteristics of fruit and vegetables [1]. Total phenolic content was determined in fresh pumpkin fruit as well as in pumpkin pulp baked. Following the laboratory determinations, the following values were found phenolic compounds, found in our research, respectively 36.03 mg/100g for pumpkin pulp fresh and 40.40mg/100g for pumpkin pulp baked (Table 3). The concentration of polyphenolic compounds in pumpkin depended on the degree of ripening. The content of polyphenolic compounds in ripe fruit was 33.5 mg/100 g dm, whereas in unripe fruit it was 10.3 mg/100 g dm. This content was similar to the results observed in methanol–aqueous extracts in the C. maxima 'Marina di Chioggia', and 'Jumbo Pink Banana' cultivars [3, 21, 26].

The results obtained were in accordance with the literature data, the amounts are found in intervals between 90 mg GAE/100 g [7] and 24 mg/100 g FW, the lowest value detected by [24]. As it could be expected, in pumpkin products lower but still significant amounts of phenolics were determined and the registered reductions were probably due to the thermal processing.

The determination of the antioxidant activity was carried out with the help of the UV - VIS spectrometer. The fresh pumpkin flesh sample has an antioxidant activity of 1.746 mM Trolox equiv/100g ripe pumpkin flesh has a value of 1.751 mg equiv Trolox/100 g. Content of antioxidants in baked pumpkin is much higher than in fresh pumpkin flesh. These results show that heat treatment does not influence the antioxidant activity of pumpkin pulp [29].

Pumpkin is an excellent source of carotenoids, especially at peel and pulp level. The yellow to orange color of pumpkin peel and flesh is due to present of carotenoids. High carotenoids contents is present in varieties showing more yellow color [34]. Pumpkin pulp pigments are widely used as additives in food products, in medicine and in cosmetics. Pumpkin pigments include carotenoids, lutein and zeaxanthin. The carotenoids are responsible for the characteristic yellow-orange color of pumpkins [34].

The orange color of the skin and flesh of the pumpkin is due to the high content of carotenoids located in the two parts of the fruit [3]. The high content of carotenoids is present in varieties that show a more intense orange color [34]. Pigments (eg carotenoids, lutein and zeaxanthin) from pumpkin pulp are widely used as additives in food, medicine and cosmetics [34].

In fact, the yellow color of pumpkin at its young stage develops to orange in its ripened stage due to a increase by 11 fold in the carotenoid content of the fruit [18, 32]. Carotenoids are considered major source of vitamin A, important for our human body improving eyesight, immune system, reproductive system, growth and development.

The content of carotenoid pigments determinate by UV-VIS method, at the analysed samples, shows that great pumpkin flesh raw and baked are rich in source of carotenoids. The sample with pumpkin pulp fresh has a total carotene content of 0.776 mg/100 g and in the baked pumpkin pulp it has a value of 2,388 mg/100 g. It was found that the total carotene content in the cooked pumpkin is much higher than in the fresh pumpkin. β-carotene is found in vegetables (carrots, apricots, spinach, potatoes, pumpkin, and pepper), oranges, and yellow fruits. Several studies have revealed the prophylactic potential of carotenoids for cancer, diabetes, inflammatory diseases and cardiovascular diseases.

Studies support the ingestion a large number of vegetables and fruits which has a high carotenoid content, and that has a protective role to the consumption of a type of carotenoid-based product. Thus, the diversification of vegetables and fruits is a prophylactic strategy, more effective, compared to the intake of carotenoids from a single vegetable product.

## CONCLUSIONS

In recent years the consumption of fruits and vegetables has increased rapidly due to the awareness of their health benefits for people. These plant ingredients come with phytochemicals, such as carotenoids and phenolics, which are believed to reduce the risk of developing degenerative and chronic diseases. The results of our study indicated that the tested pumpkin pulp, fresh and ripe, is a valuable source of carotenoids and phenolics. In other words, pumpkin is an edible ingredient, ideal for the bakery industry.

Incorporating the pumpkin pulp in gluten-free formula creates the opportunity for innovation and development of novel products. So, the pumpkin pulp, used in raw or cooked form, of this pumpkin variety could be the most suitable to enrich manufactured foods with dietary fiber. The use of *Cucurbita maxima* pumpkin pulp, obtained from local organic farms, has a high nutritional value, and inserted into various bakery formulas, lead to obtaining a food with a functional role in the body, easy processing, appropriate behavior when baking, and products with color identity. In conclusion, pumpkin pulp seems to be a valuable source of active compounds for baked products. In conclusion, pumpkin pulp seems to be a valuable source of active compounds for baked products.

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# RESEARCH ON INCREASING WORK EFFICIENCY IN THE MECHANISATION OF GERMINATION BED PREPARATION WORKS

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***Abstract***

*The aim of this work is weed control by cutting, pulling from the ground and covering with a thin layer of ground, where they can regenerate. The good preparation of the germination bed allows the seed to be covered with a well-aerated, heated soil layer and stand on a more stable and favourably humid soil. The lack of weeds and vegetable residues on the surface of the soil and on the depth of the germination bed gives it the appropriate quality to be sown. The preparation works of the germination bed were carried out at the "December 3, 1990" commercial company from Periam, Timiș County, Romania. The main methods utilized to optimize the use of agricultural aggregates are mathematical programming, direct calculus solutions, and operating nomograms. The purpose of the secondary works performed after ploughing consists in the crushing of soil clogs and of structural soil macro-aggregates in order to carry out the sowing. For the execution of the mechanised scarification works, the preparation of the germination bed and of maize sowing, the types of tractors are chosen according to the technological process of the works and to the biological properties of the crops, depending on the following indicators: light, gauge, size of equipment, plot size, energy consumption of agricultural machines, state of the land, humidity, and manoeuvrability. Soil works have been an integral part of agriculture since the beginnings of farming and they have served several important goals: the preparation of the germination bed, the reduction of soil compaction to increase aeration and allow the root system to develop optimally, the reduction of weeding, the incorporation of fertilizers and amendments, and the management of plant debris. Following the study, we can conclude that the optimization of the use of agricultural aggregates in operation contributes to the reduction of the production expenses, of the specific fuel and material consumption, and of the labour requirement.*

***Key words*****:** *economic efficiency, germination, soil*

## INTRODUCTION

The efficiency of the work depends primarily on the degree of mechanization in agriculture, because the use of agricultural machines and equipment increases the productivity of the work, relieves physical work, and reduces production expenses, thus contributing to the obtaining of increased agricultural productions [20].
The purpose of the secondary works performed after the ploughing consists of the fragmentation and crushing of the structural clogs and macro-aggregates, in order to carry out the sowing [7], [2].For the execution of mechanized works in the preparation of the germination bed, the types of tractors are chosen according to the technological process of the works and the biological properties of the crops, according to the following indicators: light, gauge, size, plot size, energy consumption of the agricultural machines, land state, soil moisture and manoeuvrability [17, 22].
Machines in agriculture, as well as in the other fields of activity, are mobile assets whose use determines a significant increase in labour productivity and a reduction in living expenses. The specific character of the use of the land as the main means of production in agriculture has a particular impact on the use of agricultural machines [3], [9], [14].

Agricultural machines need to meet the following requirements:
-provide qualitative working indices according to the requirements of modern agriculture
-execute as many technological work operations as possible
-have a multifunctional character (i.e., allow different working equipment to be adapted to the basic machine)
-be highly reliable
-be able to perform high precision works without loss of materials or crop
-ensure the mechanization of all operations within the technological production processes at a high coefficient of safety in operation and at a low production cost [6], [8].
Agricultural machines are fundamentally distinguished from machines used in other branches of the economy and especially those used in the processing industry since they work with living organisms (plants), with non-homogeneous materials in which different physical, chemical and biological processes take place [11], [16].
This needs certain requirements, specific only to agricultural machines, namely, that the technological processes executed by them create optimal conditions for plant development according to agro-biological requirements for agricultural production [1], [10], [18].

## MATERIALS AND METHODS

The preparation works of the germination bed were carried out at the "December 3,1990" commercial company from Periam, Timiș County. The germination bed or the soil layer to be sown corresponds qualitatively if the following conditions are met:
-it has an adequate depth in relation to the species to be sown
-it is shredded, without large bulges and the surface is levelled
-it is aerated and moist on the depth of sowing
-it is devoid of weeds and vegetable residues on the surface.
The optimum depth of the germination bed is equal to the sowing depth or to maximum 1-2 cm deeper, but never less.
With the increase of the moving speed of the aggregate, the working depth decreases. At the first passage over the land, the working depth is uneven; it increases significantly at the second passage, when a uniformization of the surface occurs.
The degree of soil shredding when preparing the germination bed must be normal, i.e., no more than 5-7% bulges below 5 cm on the surface of the soil: 5% of them can even exceed this size if they do not prevent the seed incorporation into the soil and if they allow keeping row distance, for example in cereals. Soil shredding should not be exaggerated; if it can be sown under optimal conditions and the seed does not remain on the surface of the soil and the remaining bulgedo not prevent the emergence, we can appreciate that the shredding was good.
A good preparation of the germination bed allows the seed to be covered with a well-aerated, heated soil layer and stand on a stable soil with favourable humidity.
The lack of weeds and vegetable residues on the surface of the soil and on the depth of the germination bed gives it the appropriate quality to be sown.
Through the works that are done when preparing the germination bed, the weeds must be destroyed by cutting, detached from the ground and not only covered with a thin layer of ground, from where they can regenerate.
When preparing the germination bed on land with rich vegetable debris, the disc harrow should not get clogged and from place to place to be raised to not accumulate the vegetable debris.
In addition to the strict quality elements of the germination bed, depth, levelling, humidity, lack of weeds, some general agrotechnical rules should also be respected, which compete both to improve the quality of the germination bed and to increase the productivity of the aggregates used.
Generally, land surfaces have a series of greater or smaller bumps, which prevent the incorporation of the seeds at the same depth, resulting in an uneven crop with holes. There are a series of cultures that require a perfect

levelling such as: clover, alfalfa, rapeseed, sugar beet, soy, etc.

The levelling can be done after the autumn ploughing, so that in spring, with less soil works, a good germination bed is ensured for the early spring sowing.

Larger bumps are removed with the help of machines with a more complex construction. In our country, they experienced with good results two traction levels: one with a working width of 2.80 m and another one with a working width of 4.25 m.

The easiest levelling or smoothing is made with a simple machine, which is a heavy iron or wood bar with a square or rectangular section. The levelling work with such simple machines is executed in aggregate with the coulter harrow, before the sowing.

In the time interval from ploughing to sowing, a significant amount of water is lost by evaporation that needs to be completed by irrigation; otherwise, there will be crop losses.

The preservation of water in the soil can be achieved by its superficial mobilization, the shredding of the bulges and the interruption of the capillarity between the 2-3 cm-surface layer, which dries, and the rest of the soil that retains its water. The soil layer from the surface prevents soil drying over a greater depth.

In the interval from harvest to sowing, the weeds are destroyed by the processing of the fields and the preparation of the germination bed. The effect is maximum when the weeds are still young, barely rising, and the soil is dry. In wet soils, the weeds remain in the soil, even if it has been mobilized, the roots are quickly restored and the plant continues to vegetate.

The last work of preparing the germination bed must be performed on the day of the sowing or no more than 1-2 days before sowing for several considerations, one of which is the destruction of weeds to avoid their competition during the rising period with the cultivated plant [19], [21].

The rational use of the power of the tractor is one of the means of reducing energy consumption in agricultural works.

The loading coefficient of the tractor (the ratio between the actual power developed by the engine and its nominal power) need to range between 0.8-0.9.

In tractors that develop power, only in traction there is a direct connection between this coefficient and the use of the tractor.

The coefficient of use of the power developed by the tractor engine (the ratio between the power developed by the engine to perform the useful work and the total developed power) must be maintained within 0.9-0.95. This is obtained by the composition of dynamically balanced aggregates with reduced masses in the rotational movement and with its own reduced mass [4], [5].

*Equipping tractors with technical means for their use in optimal parameters (additional weights, double wheels, semi-caterpillars) mechanical and hydraulic devices for increasing adherence*

The composition of aggregates with optimal operating parameters is also an important way to reduce diesel consumption.

One can choose an optimal ratio for the work speed and the width of the aggregate, considering that, at high working speeds, the energy consumption is higher, and at increased work widths, consumption is lower.

*The composition of complex aggregates, which will perform several works on a single passage*

Aggregates with which three or five works can be performed at a single passage. These aggregates are energetically advantageous and, with them, one can perform good quality agricultural works during optimal agrotechnical periods.

Fuel consumption in agricultural works with complex aggregates is lower by 20-50% compared to the consumption registered with the works performed with individual agricultural aggregates [12].

*The realization of organs of agricultural machines and machines with which agricultural works with low energy consumption can be performed*

*Use of vibrations when processing the soil, processing of work organs to reduce friction*

Promoting, in production, of technologies with low energy consumption and eliminating some intensive energy works:

-higher by 15-20%, it turns out that the gliding exceeds 15%; it is necessary to reduce the working depth or itswidth.
-lower by 15-20%, it turns out that the gliding is lower; the depth or width can increase.
[13], [15], [1].

## RESULTS AND DISCUSSIONS

For the work of preparing the germination bed, a John Deere tractor with 60 HP engine was used in good working condition.
The tractor was provided with a device for determining fuel consumption, as well as two weights of 47.5 kg each, mounted on the engine wheels.
The mass of the tractor prepared for trial was 3,750 kg.
The air pressure was regulated and kept constant during the experiments at 1.2 atm (1.18 bar). Initially, the engine regulator feature was also raised.
The data and regulator characteristics are presented in Table 1.

Table 1. Data on the John Deere 60 hp engine regulator feature

| Values measured | | | | Values calculated | | | |
|---|---|---|---|---|---|---|---|
| Motor shaft turation n, (rot/min) | Break force F, (daN) | Fuel consumed a v, (g) | Trial duration t, s | Real engine power HP | Hourly fuel consumption C, kg/h | Specific fuel consumption $g_5$, g/HPh | Engine moment $M_m$, m, daN |
| 1950 | 1.10 | 39.60 | 50 | 3.00 | 2.85 | 950 | 1.10 |
| 1918 | 8.40 | 80.80 | 60 | 22.50 | 4.85 | 218 | 8.30 |
| 1900 | 15.45 | 88.00 | 44 | 41.00 | 7.20 | 176 | 15.45 |
| 1865 | 24.00 | 191.72 | 68 | 62.00 | 10.15 | 163 | 23.90 |
| 1850 | 24.19 | 137.50 | 45 | 62.50 | 11.00 | 176 | 23.20 |
| 1825 | 25.40 | 230.40 | 70 | 64.70 | 11.85 | 183 | 25.40 |
| 1800 | 25.80 | 262.16 | 78 | 64.85 | 12.10 | 186 | 25.90 |
| 1795 | 25.85 | 79.33 | 24 | 64.80 | 11.90 | 184 | 25.90 |
| 1705 | 26.88 | 80.55 | 25 | 64.00 | 11.60 | 181 | 26.90 |
| 1605 | 27.84 | 190.00 | 60 | 62.40 | 11.40 | 18-2 | 29.90 |
| 1440 | 28.60 | 151.50 | 54 | 57.50 | 10.10 | 176 | 28.60 |

Source: Own determination.

The actual work for establishing the optimal working regime was executed on a plot with an area of 1.5 ha.
The soil was a chernozem, the land has a 3° slope in the NW direction.
The previous culture was winter wheat.
The stubble was ploughed 30 cm deep.
The ploughed land remained totally devoid of weeds, to be sown with the 2nd crop.

The machines in the aggregate (GD 3,4 harrow, levelling blade) were in good condition, being checked and adjusted.
The angle of tilting of the batteries with discs from the GD-3,4 harrow was 15°.
After the aggregates were checked and regulated, 1.5 ha was worked, after which the appropriate adjustments were corrected.
Working parameters
The average working depth for the four speeds, for which the measurements were made is shown in Table 2.
The working width is 3.4 m. This value resulted in that the tilting angle of the batteries from GD-3,4 was maximum 15°.
The degree of soil breaking up was determined with the relationship:

$G_{ms}= M_{sc}/M_{st} x 100 (\%)$..........................(1)

where:
$M_{sc}$ = mass of clogs larger than 5 cm
$M_{st}$ = total mass of aerated soil
The values of the degree of breaking up for the four speeds are shown in Table 2.
It is found that, at higher work speeds, its values increase and vice versa, as the speed of the aggregate decreases, the degree of shredding decreases.
The degree of soil aeration was determined with the relationship:

$G_{as} = h_m/a_m x 100 (\%)$...............................(2)

where:
$h_m$ = height of soil level after the passage of the aggregate
$a_m$ = average work depth
The values determined for the four speeds are shown in Table 2. It is found that the values of the aeration are raised due to the maximum angle of tilting of the discs, as well as the existence of the harrows in the aggregate.
The degree of soil levelling was determined with the relationships:

$G_{n}s = h_{md}-hc_{li} x 100 (\%)$..........................(3)
$G_{ms}= (h_{md}-h_{mi})/h_{mi} 100 \%$.........................(4)

where:

$h_{mi}$ = average distance from soil surface to rule before the passage of the aggregate (cm)
$h_{md}$ = average distance from soil surface to rule after the passage of the aggregate (cm)
The values of the levelling degree calculated following the measurements performed are shown in Table 2. An increase in the levelling degree is observed with the decrease of the speed of advancement of the aggregate. However, the high values of the levelling degree are due to the presence in the aggregate of the levelling blade.
The degree of weed destruction was not determined, as the land was deprived of weeds, its preparation for the sowing being done immediately after the ploughing.

Table 2. Values of qualitative working indices

| Gear | Average vork depth of the J.D. 60 CP + GD 3,4 Level. + 2 GCR 1,7 cm | Aggregate working width B1(m) | Soil aeration degree ($G_{ms}$%) | Soil breaking up degree ($G_{ns}$%) | Soil levelling degree % | Weeds control degree Gas (%) x |
|---|---|---|---|---|---|---|
| lll.F | 9.70 | 3.35 | 32.50 | 62.30 | 40.10 | - |
| IV. | 9.72 | 3.35 | 32.90 | 62.40 | 40.30 | - |
| lll.î | 9.87 | 3.35 | 33.20 | 60.10 | 41.40 | - |
| II.R | 9.84 | 3.35 | 34.00 | 60.20 | 41.53 | - |

x) The land was prepared immediately after the ploughing for the second crop and therefore it was deprived of weeds
Source: Own determination.

*Energy indices*

The working speed was established by timing the time to travel the distance of 100 m for the four speeds, with the relationship:

$V = 3.6 \times S/T$ (km/h)..................................(5)

where:
S = distance covered =100 m
T = time in sec.
The gliding of the motor wheels was established with the help of the relationship, where we determined the skating for the four speeds (III.R, IV. î., III. Î., II.R):

$\delta = (n_s - n_g)/n_s$............................................(6)

where:
$n_s$ = average number of rotations in operation
n, = average number of rotations at rest
It is found that the values of the gliding fall between the limits allowed (15-20%), the highest value being in the speed IV.î.

The hourly fuel consumption (G) was determined with the speed and skating using the consumer apparatus, using the relationship:

$G = 3.6/t \times V \times g$ (kg/h).............................(7)

where:
V = volume of fuel consumed (cm)
g = specific weight of Diesel (g/cm$^3$)
t = trial duration (s).
The determinations were made for the four speeds.
There is a decrease in the hourly consumption of fuel at the lower speed.
The effective power necessary for the aggregate ($N_ef$) was determined from the engine regulator feature, which equipped the tractor based on the obtained fuel consumption. Also from the regulator characteristic, the value of the nominal power ($N_m$) was established.
The loading of the engine (I) was determined by reporting the values of the two established powers above $N_ef$ and $N_m$, with the relationship:

$1 = N_{ef}/N_m \times l00$ (%)................................(8)

The values of the engine loading degree are passed in Table 3.
The traction power ($N_t$) of the aggregate for each gear was calculated separately with the relationship:

$N_t = (R_{in} \times V)/270$ (CP).............................(9)

where:
$R_{in}$ = resistance to ii action of the aggregate;
V = working speed for each of the four gears
In order to have a clearer image on how to use the nominal power of the engine, the power required to self-deposit the tractor was calculated ($N_r$).
Operation trials
Analysing the results presented above and taking into account that the tractor engine does not work in overload (lîl.R), it can be established, that the optimal working regime in a heavy soil with soil humidity up to 18-20% on plane or slope of maximum 6° would be:

-working with 9.84 cm
-working speed 5.6 km/h (II.R)
-aggregate resistance 1,128 daN
-gliding 12.9%
-hourly consumption 9.7 kg/h

It can also be seen that, from the point of view of the degree of test of the engine (without working in overload), the optimal working regime previously is appropriate.

The operation of the work aggregate John Deere + GD-3,4 + 2 GCN-1,7 and time element are shown in Table 3.

Table 3. Elements of working time

| Symbol and name | Time | Value(min) |
|---|---|---|
| Ti = real working time | The time during which the aggregate having the active bodies under load, executes the work process | 1,890 |
| T21 = return time | The time during which the aggregate moved in the void, at the ends of the plot, executing the return in charge | 188 |
| T31 = time for daily technical maintenance | The time in which the daily technical maintenance operations were performed, in order to maintain the aggregates in working condition | 80 |
| T41 = time for technological deficiencies | The time used to remove the clogging of active organs | 452 |
| $T_{42}$ = time for technological deficiencies | The time used to diagnose and remove the technical defects that occurred in the group of working machines in aggregate | 278 |
| $T_4$ = time for technological deficiencies | $T_4 = T_{4}i + T42$ | 730 |
| $T_5$ = time for staff | The time used to diagnose and remove the technical defects that occurred in the group of working machines in aggregate | 312 |
| $T_{61}$ = time for moving from headquarters to plot and vice versa | The time when the aggregate went away from the mechanization section | 468 |
| $T_7$ = time for technical maintenance at the energy source | The time in which daily technical maintenance operations were performed at the tractor | 38 |

Source: Own determination.

The grouping of working time elements represents the structure of the work time presented in Table 4.

Table 4. Structure of working time

| Symbol | Name | Definition | Value (min.) |
|---|---|---|---|
| T02 | Operative time | T02 " Ti + T21 | 2,078 |
| T03 | Total operative time | T03 T02 + T31 | 2,158 |
| T04 | Production time | T04 " T03 + T4 | 2,888 |
| T07 | Time of shift | T07 = T04 + T5 + T61 + T7 | 3,706 |
| T | Performance time | $T = T_1 + T_{21} + T_{"} + T_5 + T_{61} + T_7$ | 2,976 |

Source: Own determination.

The coefficients of time use, which constitute operating indications that characterize the activity during the working time in order to appreciate the aggregate, are represented in Table 5. The working capacity of the aggregate representing the working volume performed in the unit of time is represented in Table 6.

Table 5. Coefficients of time use

| Symbol | Name | Definition | Value (min.) |
|---|---|---|---|
| K02 | Coefficient of operative time use | K02 = T1/T02 | 0.910 |
| K03 | Coefficient of total operative time use | K03 = T-t/To3 | 0.877 |
| K04 | Coefficient of production time use | K04 = T1/T04 | 0.645 |
| K07 | Coefficient of shift time use | K07 = T1/T07 | 0.510 |
| K21 | Coefficient of return | K21 = T1 /(T1+T21) | 0.910 |
| K23 | Coefficient of technical maintenance | K23 = T1 /(T1+T23) | 0.956 |
| K41 | Coefficient of technological safety of machine organs | K41= T1 /(T1+T41) | 0.806 |
| K42 | Coefficient of technical safety | $K42 = T_1/(T_1+T_{42})$ | 0.872 |
| K4 | Coefficient of operational safety | $K4 = T_1/(T_1+T_4)$ | 0.722 |

Source: Own determination.

Table 6. Working capacity of the aggregate

| Symbol | Name | Definition | Value (ha/h) |
|---|---|---|---|
| $W_{ef}$ | Hourly working capacity in real time | $W_{ef} = U/ T_1 \times 60$ | 1.590 |
| $W_{02}$ | Hourly working capacity in operative time | $W_{02} = U/T02 \times 60$ | 1.080 |
| $W_{03}$ | Hourly working capacity in total operative time | $W_{03} = U/T_{03} \times 60$ | 1.390 |
| $W_{04}$ | Hourly working capacity in production time | $W_{04} = U/T_{04} \times 60$ | 1.040 |
| $W_{07}$ | Hourly working capacity in sift time | $W_{07} = U/T_{07} \times 60$ | 0.808 |
| $w_p$ | Working capacity | $W_p = U/T \times 60$ | 1.010 |

Source: Own determination.

Fuel consumption per ha was established using the formula:

$C_{ha}$ = Q/U................................................(10)

where:
Q = 365 kg – total fuel consumption
U = 1.5 ha – work volume
$C_{ha}$ = 365/50 = 243.33 kg/ha

## CONCLUSIONS

Following the trials of the aggregate formed by the John Deere tractor and the GD-3,4-disc harrow provided with a levelling blade and two harrows, conclusions and recommendations can be formulated:

- In the 3rd gear, rapid range, the aggregate cannot work because the traction force developed by the tractor is greater than the sum of the traction resistance of the aggregate machines and the resistance to self-deployment of the tractor, which makes the engine operate in overload;

- In the 4th gear, slow range, the aggregate can no longer work because the engine load is 98.5%, very close to the maximum load. In fact, in the operating tests it was not possible to work in this gear because, when larger irregularities of the land appear, the engine enters the overload, reducing the speed and power;
- In the 2nd gear, fast range, the aggregate can work because it performs a 92% engine load and a sliding of 12.9%;
- In the 3rd gear, slow range, the aggregate can work; however, the engine load is only 83%, and the capacity is lower than in the 2nd gear, fast range;
- The preparation of the land for the 2nd crop in heavy soils should be done at the same time with ploughing or immediately after the rain, otherwise the formed clogs become very compact, they can no longer be crushed, producing frequent clogs on the disc harrow (that is why the value of the coefficient K41 is low);
- The levelling blade is useful only under the conditions shown under point 5, otherwise there is a large agglomeration of clogs in front of it, the levelling effect decreases, and the traction resistance of the aggregate and the fuel consumption increase;
- In heavy soils, in general, the adjustable coulter harrows do not resist, many defects appear, and the time for their remediation increases (that is why the value of the coefficient K42 is low). Therefore, we recommend for heavy soils the use of flesh hob fields (GCM);
- The scraping knives from the batteries with discs become inefficient and, in the case of clogging, the clogs attached to the discs stop blocking the entire battery. When the soil humidity does not exceed 20%, we recommend the use of the disc harrow without scraping coulters;
- Productivity at shift time ($W_{07}$) is low in relation to productivity in real time ($VV_ef$).
- The value of fuel consumption per ha is high due to the increase in the resistance to fraction of the aggregate by using the levelling blade and of the deficiencies that appear, as well as the increase of the operating time of the tractor while cleaning and of the returns at the ends of the plot 1, M;
- Finally, we consider that the aggregate formed by the John Deere tractor with GD-3,4-disc harrow provided with levelling blade and two GCR-1,7 harrows can work in heavy soils with a humidity of up to 20%, on plane field or with a slope below 6°, the optimal working regime having the following energy and productivity indices:

- Resistance to traction – 1,128 daN;
- Hourly fuel consumption – 9.7 kg/ha;
- Engine load – 92%;
- Working speed – 5.6 km/h corresponding to the 2nd gear, fast range;
- Gliding – 12.9 %;
- Productivity – 0.808 ha/h (6.64 ha/8 h);
- Fuel consumption per ha – 7.31 kg/ha.

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# ARE SMALL-SCALE ORGANIC MAIZE FARMERS TECHNICALLY EFFICIENT? EVIDENCE FROM NIGERIA

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***Abstract***

*The paucity of information on the efficiency of organic food crops deters relevant interventions to enhance their production in order to address the health risks associated with inorganic food items. This study, therefore, investigated the technical efficiency, identified the factors influencing the productivity of organic maize farming, and measured the factor efficiency or resource productivityof organic maize farming in Nigeria. This study used data obtained from 480 organic maize farmers and analysed it using descriptive statistics, a stochastic frontier production function, and return to scale. The results revealed that organic maize farms had an average technical efficiency of 0.76, showing there is room for improvement. Organic manure, labour, seeds, education, extension contacts, and farm size significantly contributed to the technical efficiency of organic maize farming production. To improve and maintain the continuity of organic maize farming practices, farmers need to form and belong to farm-based organisations, where government and non-government organisations can support them, to facilitate the promotion of organic-based farming knowledge and obtain financial assistance.*

***Key words***: *food safety, maize production, Nigeria, organic agriculture, technical efficiency*

## INTRODUCTION

The use of agrochemical farming inputs such as inorganic fertilizers, herbicides, fungicides, and pesticides in conventional agriculture to increase agricultural output increases soil acidity and poses serious threats to humans, animals, natural resources, and the environment [7, 12, 16]. The use of inorganic inputs in conventional agriculture results in the poisoning of about 30 million people, leading to the death of 220,000 people yearly [31]. This increases the consumers' and policymakers' interest in safe and healthy foods. Organically produced food is thus an important solution to this menace. Organic foods are produced using methods of production that minimize human, animal, and plant health risks and have no negative impact on the environment [24].

The demand for organic foods has increased due to an increase in awareness of environmentally friendly and healthy foods [37, 43]. Organic farming in developing countries is growing due to increasing demand in European and North American markets [6] and an increase in organic food consumption globally [13]. Therefore, there is a need to increase organic farming to meet the demand for healthy foods with low risk. One of the most widely consumed food crops by humans and animals is maize. It is the leading cereal in Nigeria and its production serves as a means of livelihood for many people, especially rural dwellers.

Due to the economic value of maize to humans, for instance, as food, livestock feed and raw materials for industries, more attention has to be given to its method of organic cultivation to achieve its quality and healthy output. There is a need for organic maize farming to curb the health and environmental issues in the use of chemical inputs. Many organizations like the Food and Agricultural Organization, the International Federation of Organic Agricultural Movements, and the Organic Farmers Association advocate the use of organic materials for farming because of its economic value.

The benefits of organic practices have been proved in many ways. The use of organic manure, under organic farming, tends to increase soil pH. Organic materials also serve as the essential constituent of the soil, which is present in a variety of forms, ranging from animal and plant material. Effective use of organic manure enhances fruiting in maize, increases maize curb size and optimal yield will be achieved [39, 40]. Generally, organic farming reduces the risk of crop failure that can occur due to adverse weather conditions and advent of climate change [27, 41].

Despite the importance of organic maize to human health, most studies have concentrated on maize production from conventional agriculture [2, 10, 17, 18, 23, 26, 28, 29,34, 35, 36, 44]. The technical efficiency of organic maize farms is less documented as the available studies on the technical efficiency of organic farming did not focus on maize, thus creating a gap in the technical efficiency of organic maize farming, especially in Nigeria. For instance, Gogoi et al. [25] assessed the technical efficiency of tea farming in Assam, India. However, the few available studies on organic maize production were on experimental farms which were viewed from the agronomic point of view. For instance, Adamteya et al. [1] used established trials in a field experiment to compare the yield of organically produced maize and conventionally produced maize in Kenya. Similarly, Mucheru-Muna et al. [30] established experimental trials at two sites in Kenya to examine the effects of various organic nutrient sources on maize revenue and yield. Choudharya & Kumar [15] also set an experiment using a randomized block design with six treatments to examine the influence of organic nutrients on the yield and growth of maize in India. Therefore, this study intends to fill this gap and add to the existing knowledge on organic farming.

From the foregoing, the present study adds to literature by using data from organic maize farmers to assess the technical efficiency of the farms. Specifically, the study assessed the technical efficiency of organic maize farming, identified the factors influencing the productivity of organic maize farming, and measured the factor efficiency or resource productivity of organic maize farming. These would help farmers, researchers, extension agencies, government parastatals, as well as various policymakers with empirical evidence on technical efficiency of organic maize farming. This will, in turn, serve as a policy material for organizations and the government at large to enhance organic farming and food safety. It will also serve as a reference material for individuals willing to undertake research into the efficiency of organic maize farming.

## MATERIALS AND METHODS

### Study area

The study area is Nigeria. Nigeria lies between longitudes $3^0$ and $14^0$ East and latitudes $4^0$ and $14^0$ North and has a total land area of 923.768 $km^2$ [32]. Agriculture is the major source of employment and livelihood, employing 70% of the population.

### Samplingtechnique and data collection

The respondents were selected using a multi-stage sampling technique. It involves a purposeful selection of two leading states (Niger and Kaduna) in maize production, in stage one. After this, a random selection of four local government areas (LGAs) was done from each state. This is followed by selection of three communities from each LGA, randomly. In the fourth stage, twenty organic maize farmers were selected from each rural community using the snowball technique; this gave a total of 480 respondents.

Data was collected through the administration of questionnaires to the organic maize farmers. Data was collected on socioeconomic and production characteristics. The data includes age, gender, monthly income, primary and secondary occupation, household size, level of education, marital status, membership of farmer-based organization, years of farming experience, total farm size for organic maize cultivation, and access to extension services by the farmers. The variables were selected based on the design of the research and literature. Also, information regarding organic maize farming was sought from the respondents. It includes the quantity of inputs used in its production. Data was collected in February and March 2021 by the researchers and trained research assistants.

**Methods of data analysis**

Descriptive statistics, stochastic frontier production function (SFPF), and return to scale (RTS) were means of data analyse.

**Descriptive statistics**

Descriptive statistics is a statistical technique that produces figures or numbers that describe or summarize a set of data. The descriptive statistical analyses used were the measure of dispersion and a measure of central tendency such as percentage, frequency distribution table, and mean. This was used to present the findings of organic farmers' technical efficiency.

**Stochastic frontier production function (SFPF)**

To investigate the productivity of organic maize farming and determinants of its efficiency, the Cobb-Douglas form of the SFPF was used. This has been widely used in previous studies as it meets the requirement of being self-dual [8, 9, 17,19, 25, 38, 42]. It can also be used to estimate the returns to scale in a production function.

The model is implicitly specified as:

$$Y = f(X_i, \beta_i) + V_i - \mu_i \quad \text{..........(1)}$$

The technical efficiency model is explicitly represented as:

$$lnY = \beta_0 + \beta_1 lnX_1 + \beta_2 lnX_2 + \beta_3 lnX_3 + \beta_4 lnX_4 + V_i - \mu_i \quad \text{..........(2)}$$

where:

In = natural logarithm

Y = Yield of organic maize (kg)

$X_1$ = labour (man/days)

$X_2$ = seed (kg)

$X_3$ = quantity of organic manure used (kg)

$X_4$ = farm size (hectares)

$B_1$-$\beta_4$ = coefficients

$B_0$ = constant

Vi-Ui = composite error terms

Vi is the random variables that are consideredindependent of ui. It is normally distributed with constant variance and a zero mean N (0, δ $v^2$). It accounts for error measurement and other factors which are not under the control of the organic farmer such as disease and weather.

Ui = non-negative random variables that are considered to be independent of vi. They account for the technical inefficiency in organic maize farming. The inefficiency of organic maize farming, Ui, is modelled in terms of the factors related to socioeconomic features of the organic maize farmers assumed to influence the efficiency of organic maize farming. The model was jointly estimated with equation (3) and is expressed as:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 \quad \text{..........(3)}$$

where:

$U_i$ = technical inefficiency

$Z_1$ = Farming experience in years

$Z_2$ = Farmers' age in years

$Z_3$ = Household size (number)

$Z_4$ = Education (years)

$Z_5$ = Contact of extension agent (number of contacts)

$\delta_0$ (intercept) and $\delta_{1-5}$ (coefficients) are parameters to be estimated.

The gamma (γ) will be determined. This is the percentage of output divergence from the frontier caused by technical inefficiency. The sigma square ($\delta^2$) will also be estimated. It indicates the model's goodness of fit and the correctness of the distributional assumption.

**Returns to scale (RTS) in organic farming production**

Measurement of factor efficiency or resource productivity was done using RTS. A measure of RTS is calculated by summing the regression coefficients of the predicted functions of all independent variables in the frontier production function. It is expressed as:

$$RTS = \sum \beta_i \quad \text{..........(4)}$$

where:

RTS = Returns to scale

$\beta_i$ = regression coefficient.

If RTS > 1, it suggests an increasing RTS

If RTS < 1, it suggests decreasing RTS

If RTS = 1, it suggests a constant RTS.

## RESULTS AND DISCUSSIONS

### Technical efficiency levels of organic maize farms

Table 1 presents the level of technical efficiency of the organic maize farmers. The value ranged between 0.47 and 0.95 with an average of 0.76. The average technical efficiency implies that there is still a gap of 0.24 (or 24%) between the current organic farmers' technical efficiency and the production frontier. This suggests that if the efficiency of input usage by organic farmers is increased by 24%, the organic maize farmers will be operating on a production frontier. Further analysis revealed that 60.8 per cent of the farmers were operating above this average, while 39.2% were operating below it.

Table 1. Distribution of the organic farmers by technical efficiency

| Technical efficiency | Frequency | Percentage | Minimum | Maximum | Mean |
|---|---|---|---|---|---|
| 0.41 - 0.50 | 10 | 2.1 | 0.47 | 0.50 | 0.49 |
| 0.51 - 0.60 | 45 | 9.4 | 0.57 | 0.60 | 0.59 |
| 0.61 – 0.70 | 101 | 21.0 | 0.63 | 0.68 | 0.66 |
| 0.71 - 0.80 | 185 | 38.5 | 0.74 | 0.79 | 0.77 |
| 0.81 - 0.90 | 91 | 19.0 | 0.86 | 0.90 | 0.88 |
| 0.91 - 1.00 | 48 | 10.0 | 0.91 | 0.95 | 0.93 |
| Sample | 480 | 100 | 0.47 | 0.95 | 0.76 |

Source: Field survey, 2021.

### Productivity of organic maize farming

### Efficiency estimation

The maximum likelihood estimates of the organic farmers is presented in Table 1. The estimated variance ($\delta^2$) was significant. This indicates the correctness of the specified distribution assumption of the composite error term and the goodness of fit. In the same vein, the estimated gamma (0.9532785) was significant. This indicates that 95.3% of the total difference in the farm yield of the organic farmers was due to technical inefficiency. Furthermore, the coefficients of organic manure, labour, and farm size were positive and significant, while that of seed was negatively significant.

The positive coefficient of organic manure indicates that it has a direct relationship with organic maize output. This implies that a proportionate increase in the use of organic manure while other explanatory variables remain constant will result in an increased organic maize output level. The result indicates that the use of organic manure would result in a higher yield of organic maize farming production, all things being equal. This could be because the output of crops depends on the soil nutrients; thus, the use of organic manure will enhance soil nutrients and consequently increase the organic maize yield. This conforms to the findings of Gogoi et al. [25] that organic manure increases the total output. Anang et al. [5] and Uuld et al. [38] also stated that crop output is heavily dependent on manure.

The estimated positive coefficient of labour shows a direct relationship between labour and organic maize output. This result shows that an increase in labour usage will increase organic maize farming output. Labour is crucial in agriculture, especially in developing nations where the most farmers use crude implements [14, 33]; thus, as efficient labour usage increases, farmer efficiency and output increase. This supports Bozoglu and Ceyhan [11], Anang et al. [5], and Uuld et al. [38].

The negative coefficient of seed implies that an increase in seed usage by farmers will not necessarily increase the output of organic maize. As the farmers increase the quantity of seed used per hectare, a diminishing marginal return sets in. This could be because organic maize farming has a specific planting space (75cm by 50cm) which is being used in the study area. Thus, any increase in seed rate per hectare will cause overpopulation of the crop and competition for space and nutrients, which, in turn, may lower the efficiency and productivity of organic maize farming. A similar finding was also reported by Bairagi and Mottaleb [8] that seed negatively affected farm production efficiency.

The positive sign of the farm size shows that farm size contributes immensely to the technical efficiency of organic maize production. An increase in farm size will increase the efficiency level of organic maize production. This could be due to the enjoyment of economies of scale, which is possible at large farm sizes. Farmers will buy the required inputs at a cheaper rate, which will, in turn, enhance their production efficiency. This supports Bidzakin et al. [9] and Uuld et al. [38] that farm size (land) enhances productivity.

Table 2. Maximum likelihood estimates of the SFPF of organic maize production

| *Variables* | *Coefficient* | *Standard Error* | *z* | *P>\|z\|* |
|---|---|---|---|---|
| *Efficiency model* | | | | |
| Constant | 10.3581 | 1.2863 | 8.05 | 0.000 |
| Labour | 0.2109** | 0.0833 | 2.53 | 0.012 |
| Seed | -0.4496*** | 0.0988 | -4.55 | 0.000 |
| Organic manure | 0.0011** | 0.0005 | 2.23 | 0.026 |
| Farm size | 0.2037*** | 0.0349 | 5.84 | 0.000 |
| *Inefficiency Model* | | | | |
| Constant | 1.0927 | 0.9883 | 1.11 | 0.269 |
| Age | 0.0647 | 0.2999 | 0.22 | 0.829 |
| Household size | 0.3401 | 0.2218 | 1.53 | 0.125 |
| Farming experience | -0.1703 | 0.1085 | -1.57 | 0.177 |
| Level of education | -0.1644*** | 0.0596 | -2.76 | 0.006 |
| Extension contacts | -0.0371** | 0.0371 | -2.15 | 0.042 |
| Sigma-squared ($\delta^2$) | 0.9298*** | 0.2227 | 4.17 | 0.000 |
| Gamma ($\gamma$) | 0.9533*** | 0.2749 | 3.47 | 0.006 |

Wald chi2(3) = 7.92 Prob > chi2 = 0.0477 Log likelihood = -132.3770
*$p$< 0.1; **$p$< 0.05; ***$p$< 0.01
Source: Survey data, 2021.

**Inefficiency estimation**

The inefficiency factors were chosen to reflect the farmers' unique socio-economic conditions. Negative coefficients imply that the variables increase the efficiency of organic maize production, whereas a positive coefficient indicates the opposite, that is, it reduces the efficiency. As shown in Table 2, educational level and extension contacts were negatively significant. The estimated coefficient of the educational level was negative concerning the inefficiency of organic maize production. This suggests that the technical efficiency of organic maize farming increases as the educational level increases and vice versa. Thus, educated farmers were more efficient in organic maize farming. This could be due to educated farmers being well informed on technical know-how, adopting innovation, and obtaining agricultural information [20, 21, 22], resulting in production near the frontier. This agrees with Gogoi et al. [25], and Wu [42] that formal education increases crop production efficiency.

Contacts with extension agents influenced organic maize farming inefficiency negatively. This implies that access to extension services increased the technical efficiency of organic maize production. Farmers who had access to extension services were more efficient in organic maize farming than those without extension contact. This could be a result of information on best farming practices, innovation, training, and technical support gotten from the extensionists [3, 4]. This supports Falola et al. [19] that extension contacts increased production efficiency.

**Returns to scale in organic farming production**

The result of returns to scale used to measure resource productivity or factor efficiency of organic maize production is presented in Table 3. The return to scale was -0.0339. The negative sign of the computed RTS indicates a decreasing return to scale. This shows that organic maize farmers stopped their production when the average productivity of variable resources was declining and total physical product reached its peak but increased at a decreasing rate. This is a rational, optimal, and economical stage of production. The result implies that the organic maize production resources were efficiently utilized by the farmers.

Table 3. Returns to scale of organic maize production

| *Variables* | *Elasticity* |
|---|---|
| Labour | 0.2109 |
| Seed | -0.4496 |
| Organic manure | 0.0011 |
| Farm size | 0.2037 |
| RTS | -0.0339 |

Source: Survey data, 2021.

## CONCLUSIONS

This study investigates the technical efficiency of organic maize farming. The study showed that organic maize farms had an average technical efficiency of 0.76, showing that there is room for improvement on the part of the farmers. The analysis of the drivers of productivity of organic maize farming reveals that the use of organic manure increases maize yield, whereas increasing labour and seeds does not necessarily increase organic maize output per hectare. In addition, farmers' educational level, extension contacts, and farm size enhance the technical efficiency of organic maize farming.

This study recommends the encouragement of farmers to form and belong to cooperatives or farm-based organizations to facilitate the promotion of organic-based farming knowledge among themselves. Adequate funding should be provided by governments and NGOs to enhance judicious research in developing feasible and sustainable organic agricultural practices. They could also, through relevant ministries, assist in efficient monitoring and evaluation of the production systems in organic farming. Also, efforts should be geared towards improving the educational level of the farmers, as this will increase their level of technical efficiency. This could be done through organizing literacy programs for the farmers.

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# CARBON FOOTPRINT ESTIMATION IN EGYPTIAN AQUACULTURE FARMS

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***Abstract***

*This study discusses the result of a life cycle assessment (LCA) for three Egyptian aquaculture farms categorized as semi-intensive culture. The cradle-to-grave system was used to calculate the overall carbon footprint of fish unit production. The major data came from a study of three feed factories in Egypt, which included a wide range of feed manufacturing and agricultural practises in order to reveal the varied greenhouse gas (GHG) emissions. Pre-farm, farming, and post-farming were the three stages of the life cycle assessment. Feed manufacture, which was primarily tied to the production and processing of raw materials, was the largest source of GHG emissions for all three processes. GHG emissions were also produced during the transport of raw materials to the factory. GHG emissions were also produced during the transportation of raw materials to manufacturers, as well as feed from factories to fish farms, via ship or road. Energy consumption in feed factories varies due to variances in design technology and manufacturing efficiencies. Feed conversion ratios (FCR) have a significant influence on GHG emissions since more feed is required to produce one kilogramme of fish. The kind of packaging material and energy utilised in the factories had an impact on GHG emissions, as each type had a distinct emission factor (EF). Aside from fingerling production, there are direct and indirect $N_2O$ emissions, as well as post-farming operations like packaging, ice serving method, and customer transportation. The conclusions of the investigation revealed that According to the results of the study, the emissions linked with the three farms varied greatly. Hanafy farm had the greatest emissions, with 3.265 kg $CO_2e$/kg fish and 50.917 tonnes $CO_2e$/Season, followed by Hashim farm with 2.259 kg $CO_2e$/kg fish and 45.829 tonnes $CO_2e$/Season, and finally Aly farm with 2.223 kg $CO_2e$/kg fish and 38.864 tonnes $CO_2e$/Season.*

**Key words:** *aquaculture, carbon footprint, life cycle assessment, green-house gas emissions (GHG), climate change*

## INTRODUCTION

Egypt, out of all the Arab countries, is the greatest sensitive to global warming. Climate change representations project that rising sea levels would flood significant parts of Egypt's the Delta, risking Egypt's food security and the livelihoods of millions of agricultural workers. Key population areas, such Alexandria and Port Said, are also in jeopardy. Furthermore, rising average temperatures may impede Egypt's ability to grow enough food to feed its growing population, producing further disruptions in the agricultural sector, which now employs over thirty percent of the country's workers. Another danger is the influence of climate change on rainfall patterns in highland Ethiopia, which supplies more than eighty percent of the Nile River's water [23].

In Egypt, the volume of fish production in 2019 reached 2.0 million tons compared to in 2018 was 1.90 million tons, an increase by 5.4% owing to amount of farm production fish increase, where its production come in the first place, and its percentage reached 79.7%, followed by Lakes, then marine waters, then fresh water then rice fields. The value of fish production reached 61.1 billion LE in 2019 compared to 48.3 billion LE in 2018, an increase of 26.6% due to the increase in production and prices [6].

Aquaculture can be definite as the farming organisms from both the sea and the freshwater. A definition of aquaculture as the controlled production of aquatic animals such as fish, oyster, and unicellular plants [26].

Aquaculture has accounted for the majority of net growth in fish output during the last decade [8]. An aquaculture system can be classified using a variety of characteristics. In terms of economics, the most important measure is intensity, or the distinction between intense, semi-intensive, and widespread kinds of culture. Stocking density, production by area, feeding regime, and input costs are all measures of intensity, but the most interesting aspect is the degree of control within the production process or according to the fish farmed species of monoculture and polyculture [2]. Semi-intensive earthen ponds are the most common aquaculture practise in Egypt. Intensive aquaculture farming has increased in popularity in the last 15 years, particularly in the deserts of northern Sinai, based on agricultural drainage waters [12].

The majority of the aquaculture production is obtained from semi-intensive fish farms in earthen ponds, which are dispersed throughout the Nile Delta region and concentrated mostly in the Northern lakes (Manzala, Edko, Burulus, and Maruit) area. The majority production of aquaculture derives from semi-intensive clay pond fish farms [25]. Semi-intensive systems produce between 5 and 25 tonnes per hectare per year. The Nile tilapia is the most widely grown fish in both tanks besides ponds [22]. Intensive pond aquaculture is currently displacing semi-intensive ponds in significant areas. Small earthen ponds of 3,000 to 6,000 $m^2$ used in intensive pond systems, with an average production of 14 to 25 tonnes/ha [11].

Increasing temperatures diminish dissolved oxygen levels and raise fish metabolic rates, resulting in a rise in fish fatalities, a decrease in productivity or an increase in feed requirements, as well as an increase in disease risk and spread. Furthermore, climate change may have an indirect impact on aquaculture activity. Wide swaths of aquaculture ponds in low-lying places, for example, may be particularly vulnerable to sea level rise inundation [10]. Increasing temperatures diminish dissolved oxygen levels and raise fish metabolic rates, resulting in a rise in fish fatalities, a decrease in productivity, or an increase in feed requirements, as well as an increase in disease risk and spread. Furthermore, climate change may have an indirect impact on aquaculture activity. Wide swaths of aquaculture ponds in low-lying areas, for example, may be particularly vulnerable to sea level rise inundation [10].

The high levels of GHG emissions documented for some aquaculture systems as aquaculture in the top 21 fish-producing countries generates 218 Tg $CO_2$ carbon dioxide equivalent which mean the amount of $CO_2$ equivalent to the quantity of GHG gases associated with a process ($CO_2e$) $CH_4$ and 11 Tg $CO_2e$ $N_2O$ annually [29].

Due to their significant global warming potential (GWP) (34 and 298 times more than carbon dioxide ($CO_2$) over a 100-year time horizon, respectively, methane ($CH_4$) and nitrous oxide ($N_2O$) emissions are the most relevant [18].

Aquaculture is anticipated to produce more than 5% of total anthropogenic $N_2O$ emissions by 2030 [19].

Earthen shallow fish ponds are GHG emission hotspots, accounting for more than 80% of all aquaculture GHG emissions [29].

Agricultural systems account for 10 to 12 percent of global total GHG emissions; however, if all agriculture-related emission sources are included, this proportion might rise to between 17 and 32 percent (8.5-16.5 Pg $CO_2e$) [4].

LCA is a process for charting and quantifying a product's environmental consequences throughout its life cycle. The ISO 14000 set of environmental management standards includes LCA. LCA is all-encompassing since it considers the entire life cycle, or production system, as well as a complementary set of environmental implications. Global warming, acidification, eutrophication, ozone layer depletion, and aquatic eco-toxicity are some of the most common LCA impact categories [3]. The assessment of the total quantity of GHG emissions linked with a product along its supply chain is known as carbon foot printing (CF) [9].

As a result, a product's carbon footprint refers to the product's total GHG emissions over its entire life cycle, from raw materials to manufacturing, distribution, consumer use, and disposal [7].

CF estimation results will vary greatly depending on the methods used. The following system boundaries determine the life cycle stages [17]:

-Cradle-to-grave: covers emissions and removals released throughout the product's entire life cycle.

-Cradle-to-gate: includes emissions and removals up to the point where the product leaves the company.

-Emissions and removals in the supply chain are included in the gate-to-gate approach.

-Partial CF: only emissions and removals related to specific phases are included.

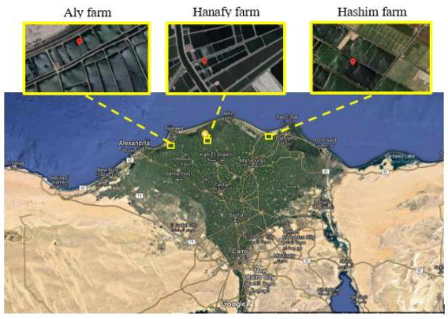
Publically available specification 2050 (PAS 2050), GHG Protocol, and ISO 14067 are the three most widely used Carbon Footprint (CF) standards in the world [5]. All three provide standards and guidance for making decisions during a carbon footprint analysis. All of them are based on existing LCA methodologies such as ISO 14040 and ISO 14044. LCA problems like as aim and scope definition, data gathering methodologies, and reporting are all part of the decision-making process. Furthermore, these criteria include requirements for land-use change, carbon uptake, biogenic carbon emissions, soil carbon change, and green electricity, all of which are important to the CF [24].

The main objectives of this study to estimate Greenhouse gases for LCA of Egyptian semi-intensive earthen ponds aquaculture and calculating fish unit production of equivalent carbon dioxide. Also, the annual emissions associated with aquaculture from raw material production across raw material transport and shipping to factories. Besides, feed manufacturing types and energy. As well as on farm energy and feed consumption and $N_2O$ emissions. Finally, post farming emissions from packaging, ice serving and transporting of final products.

## MATERIALS AND METHODS

### Materials

The current study established on three aquaculture farms located in north of Egypt these farms were Hanafy farm at Kafrelshikh government, Hashim farm at Dakahlia government and Aly farm at Elbehira government as shown in Map 1 and Table 1. There are three feed factories under study located in Damro, 6th October and Baltim cities. The aquaculture production system common was the semi-intensive.




Map 1. Location of aquaculture farms under study on Egypt satellite map
Source: Google Maps.

In the three Egyptian semi-intensive earthen pond aquacultures, the system boundary is "cradle to grave," and the life cycle assessment (LCA) was chosen as the environmental management technique to analyze the net aquaculture production sectors from a life cycle viewpoint, as illustrated in Figure A.

In this study, the International Standards Organization (ISO) 14040, 14044 outlines and PAS 2050 were applied on each stage of the LCA was detailed in figure 2. Mortality and FCR calculated as follows [21]:

- Mortality = fingerlings death + disease + treatment + categorizing + discharges.
- Yield mass = harvest mass – fingerlings mass.

FCR = Yield mass (kg)/Taken feed(kg).

Table 1. Feed contaminants and formulation

| | Units | Wheat bran | Maize gluten | Soyabean meal | Fish meal | Oil | Maize | Rice bran | Salt | Mineral and vitamin premix |
|---|---|---|---|---|---|---|---|---|---|---|
| **Dry matter%** | % | 85 | 94 | 88 | 89 | 82 | 87 | 81 | 0 | 93 |
| **Gross energy** | MJ/kgDM | 18.9 | 18.8 | 19.7 | 21.9 | 21.2 | 18.7 | 20.5 | 0.0 | 9.2 |
| **Digestible energy** | MJ/kgDM | 16.0 | 17.7 | 17.3 | 19.4 | 17.3 | 16.3 | 16.6 | 0.0 | 8.5 |
| **Nitrogen** | gN/kgDM | 23.5 | 10.1 | 71 | 106.7 | 66.7 | 15.4 | 19.5 | 0.0 | 80.0 |
| **Crude protein** | gCP/kgDM | 147 | 63 | 444 | 667 | 417 | 96 | 122 | 0.0 | 500.0 |
| **Phosphorus** | gP/kgDM | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 114.0 |
| **Feed formulate (CP 25%)** | | 15 | 5 | 32 | 3 | 2 | 20 | 21.7 | 0.5 | 0.8 |

Source: Feedipedia at www.feedipedia.org.

| Stage / GHG | Pre-farming | Farming | Post-farming |
|---|---|---|---|
| $N_2O$ | • cultivation manure use<br>• In organic N | • Fertilization of pond<br>• Direct and indirect $N_2O$ from excreted N and uneaten feed<br>• Fingerling's feed | |
| $CO_2$ | • on-farm buildings and equipment<br>• Operations energy<br>• feed material processing energy<br>• Fertilizer manufacture<br>• Production of non-crop feeds<br>• Land use change (LUC)<br>• feed packaging<br>• nurseries feed production<br>• Transport feed material to processing<br>• Transport shipping of imported feeds<br>• Transport road from port to feed mill<br>• Transport manufactured feed to farm | • pond sediments<br>• Direct on-farm energy use for pumping and lighting | • Main products and by-products processing<br>• Transport from farm to capital markets<br>• Transport from farm to medium markets<br>• Transport from farm to small markets<br>• Ice production<br>• Fish HPDE boxes |
| $CH_4$ | • Rice cultivation | Enteric fermentation | |

Fig. 1. Cradle to Grave system boundary (under study parameters are inside dotted shapes and the outside parameters aren't under study).
Source: Authors' determination.

## RESULTS AND DISCUSSIONS

After collecting data from the survey results estimated and discussed as below and emission factors for parameters and other constants collected in Tables 2 and 3.

**Firstly, Pre-farming EI**

Figure 2 showed that at Pre-farming EI stage the extruded feed for the third factory has the maximum EI with 1.283 $kgCO_2e$/kg feed and the pelleted feed at the first factory has the minimum EI with 1.043 $kgCO_2$/kg feed.

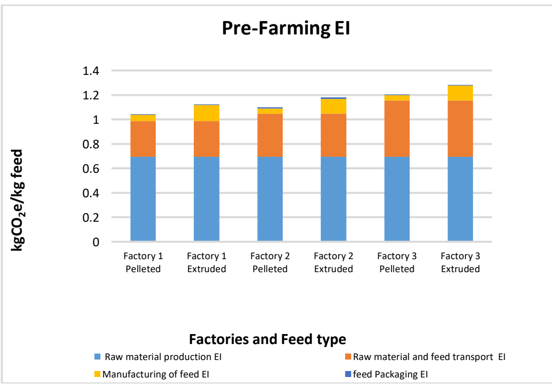



Fig. 2. Pre-farming stage main parameters EI.
Source: Own design and results.

This result was due to the effect of Transport to factory EI and the technology of manufacturing affecting on the energy consumed. Also Feed packaging material EI and transport feed to farm EI has a significant effect on the total EI.

Also, for example for the pelleted feed of factory 1, the raw material production occupied the largest percentage with 66.6% of EI and feed packaging had the lowest percentage with 0.62% EI.

Table 2. Emission factors and other constants values for different parameters and references

| No | Item | Unit | Value | Reference |
|---|---|---|---|---|
| 1 | EF of ship | $kgCO_2e/t.km$ | 0.037 | [27] |
| 2 | EF of lorries | $kgCO_2e/t.km$ | 0.085 | [27] |
| 3 | EF of vehicles | $kgCO_2e/t.km$ | 1.0818 | [20] |
| 4 | EF of electricity | $kgCO_2e/kW$ | 0.458 | [15] |
| 5 | EF of diesel | $kgCO_2e/kg$ | 3.193 | [20] |
| 6 | EF of Petrol | $kgCO_2e/kg$ | 3.01 | [7] |
| 7 | EF of PP bag | $kgCO_2e/kg$ bag | 2.69 | [28] |
| 8 | EF of PPT bag | $kgCO_2e/kg$ bag | 2.70 | [28] |
| 9 | EF of PP&PE bag | $kgCO_2e/kg$ bag | 2.695 | [28] |
| 10 | EF of HDPE boxes | $kgCO_2e/kg$ bag | 3.19 | [28] |
| 11 | Density of diesel | Kg/L | 0.832 | [1] |
| 12 | Density of petrol | Kg/L | 0.74 | [1] |
| 13 | Nitrogen use efficiency | % of feed N | 23.22 | [14] |
| 14 | N excreted | % of feed N | 76.78 | [14] |
| 15 | $N_2$ to $N_2O$ | N (44/28) | 1.5714 | [14] |
| 16 | GWP | N | 298 | [16] |
| 17 | N excreted converted to N2O-N | % | 1.8 | [14] |
| 18 | Ice manufacturing electricity | kWh/t ice | 58 | [13] |
| 19 | Ice manufacturing diesel | kg/t ice | 0.25 | [13] |

Source: Set up by authors based on the studied literature.

Table 3. LCA stages emission intensities (EI) and main parameters

| Pre-farming EI | Farming EI | Post-farming EI |
|---|---|---|
| • Raw material production EI<br>• Raw material and feed transport EI<br>• Feed Manufacturing EI<br>• Feed packaging EI | • Farming Feed and energy EI<br>• Fingerling Feed and energy EI<br>• $N_2O$ EI | • Fish high density polyethylen (HDPE) Boxes EI<br>• Ice manufacturing energy EI<br>• Transport to markets EI |

Source: Authors' conception.

## Raw material production EI

The results declared that raw material production EI is the sum of cultivation not including land use change (LUC) EI, transport to handling EI, manufacturing EI and LUC EI which were 0.415, 0.083, 0.168 and 0.027 $kgCO_2e/kg$ feed acting 39.82, 7.96, 16.14 and 2.66 % of pre-farming EI, respectively as shown in Figure 4. Every crop production has different EI as indicated in Table 4. Results shown in Figure 3 also indicated that all factories have the same value of EI of cultivation (not including LUC), transport to processing, processing and LUC as the raw material have been purchased from the same source.

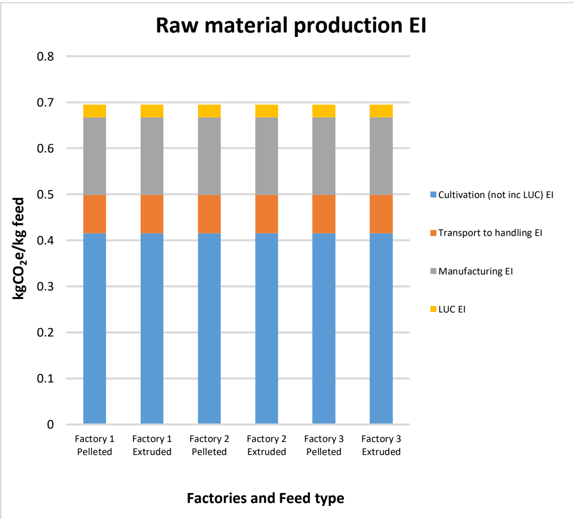



Fig. 3. Raw material production EI
Source: Own results.

The results pointed that maximum EI value for raw material production obtained for non-crop was 5.175 kg.$CO_2$e/kg dry material of mineral and vitamin premix and for crops was 1.862 kg$CO_2$e/kg dry material of maize gluten. Also, the minimum EI value for crops was 0.312 kg.$CO_2$e/kg dry material of rice bran as presented in Table 4. The analysis for this data indicated that processing stage has a significant effect on all raw materials EI.

Table 4. Raw material production EI

| | Units | Wheat bran | Maize gluten | Soyabean meal | Fish meal | Oil | Maize | Rice bran | Salt | Mineral and vitamin premix |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivation (not inc LUC)** | g$CO_2$e/kg. production | 122.0 | 317.0 | 347.6 | 440.5 | 690.0 | 727.0 | 119.8 | | |
| **Transport to handling** | g$CO_2$e/kg. production | 31.0 | 145.0 | 141.6 | 158.5 | 90.0 | | 23.8 | | |
| **Manufacturing** | g$CO_2$e/kg. production | 190.0 | 1199.0 | 90.4 | 513.1 | 95.0 | | 29.0 | | |
| **Main production** | g$CO_2$e/kg. production | 343.0 | 1661.0 | 579.6 | 1112.1 | 875.0 | 727.0 | 172.6 | | |
| **LUC EI** | g$CO_2$e/kg. production | 0 | 0 | 0 | 0 | 0 | 0 | 108.16 | 0 | 0 |
| **Total EI at production** | g$CO_2$e/kg. production | 343.0 | 1661.0 | 579.6 | 1112.1 | 875.0 | 727.0 | 280.8 | 18.0 | 5175.0 |
| **Dry matter ratio** | % | 0.883 | 0.892 | 0.874 | 0.919 | 0.928 | 0.872 | 0.899 | 1 | 1 |
| **Total EI end cultivation** | g$CO_2$e/kg dry | 388.44 | 1862.1 | 663.157 | 1210.1 | 942.8 | 833.71 | 312.29 | 18 | 5175 |

Source: Feedprint Manual.

## Raw material and feed transport EI

EI of raw material transporting consists of shipping EI for imported materials and transport from stores locally to factories EI as shown in Tables 3 and 6.

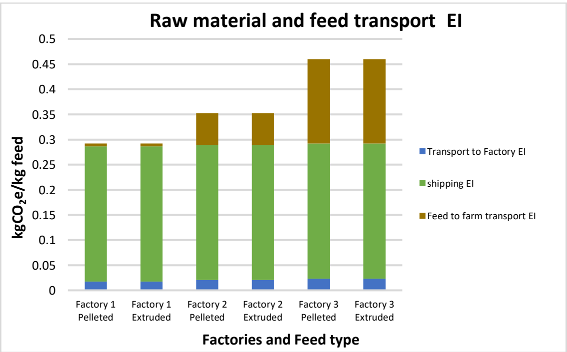



Fig. 4. Raw material and feed transport EI.
Source: Own results.

Also, for the pelleted feed of factory 1, the shipping EI acted the largest percentage with 92.2% of raw material and transport EI and feed to farm transport EI had the lowest percentage with 1.9% raw material and transport EI.

The results indicated that maximum EI for shipping was 546.49 g$CO_2$e/kg for maize gluten and minimum EI for shipping was 242.794 g$CO_2$e/kg for fish meal.

This result obviously related to the shipping distance from the importer as declared in Tables 2 and 5. The data also revealed that total transport EI was high for Maize gluten and low for salt, with 557.7 and 4.33 g$CO_2$e/kg, respectively. Since maize gluten was imported while salt was produced locally.

## Feed manufacturing EI

Data collected from survey declared that energy at factories comes from electricity and diesel. Also, the extruded feed consumed energy more than the pelleted. So, the EI for the extruded is more than the pelleted at all factories as shown in Figure 5.

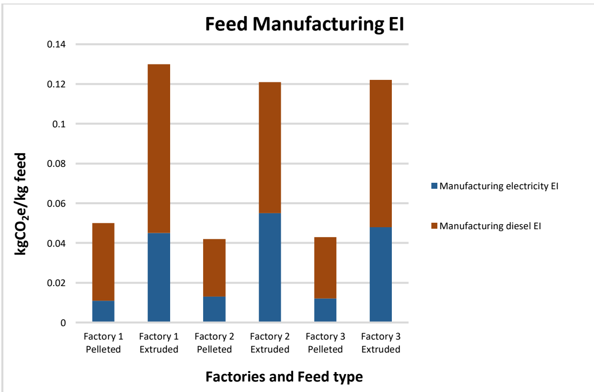



Fig. 5. Feed manufacturing EI for different factories and types feed
Source: Own results.

As well as, the minimum feed EI for pelleted feed obtained from factory 2 was 42.964 $gCO_2e$/kg.feed, while the maximum feed EI for pelleted feed obtained from factory 1 was 51.301 $gCO_2e$/kg.feed as shown in Tables 1 and 6. The differences between factories EI related to the energy use efficiency and technology type and design.

Table 5. Raw materials and feed transport EI

| | Units | Fine wheat bran | Maize gluten | Soyabean meal | Fish meal | Oil | Maize | Rice bran | Salt | Mineral and vitamin premix |
|---|---|---|---|---|---|---|---|---|---|---|
| **Origin** | | local | imported | imported | imported | local | imported | local | local | local |
| **exporter** | | - | China | USA | India | - | Argentina | - | - | - |
| **Shipping** | km | - | 14,770 | 11,621 | 6,562 | - | 13,107 | - | - | - |
| **EI of shipping** | gCO2e/kg | 0 | 546.49 | 429.977 | 242.794 | 0 | 484.959 | 0 | 0 | 0 |
| **importer to Factory 1 road** | km | 177 | 114 | 114 | 114 | 220 | 114 | 25 | 25 | 65 |
| **importer to Factory 2 road** | km | 115 | 211 | 211 | 211 | 5 | 211 | 75 | 3 | 35 |
| **importer to Factory 3 road** | km | 262 | 133 | 133 | 133 | 333 | 133 | 65 | 4 | 56 |
| **EI of factory 1 road transport** | gCO2e/kg | 15.05 | 9.69 | 9.69 | 123.33 | 238.00 | 9.69 | 2.13 | 27.05 | 70.32 |
| **EI of factory 2 road transport** | gCO2e/kg | 9.78 | 17.94 | 17.94 | 228.26 | 5.41 | 17.94 | 6.38 | 3.25 | 37.86 |
| **EI of factory 3 road transport** | gCO2e/kg | 22.27 | 11.31 | 11.31 | 143.88 | 360.24 | 11.31 | 5.53 | 4.33 | 60.58 |
| **Total Transport EI of factory 1** | gCO2e/kg | 15.05 | 556.18 | 439.67 | 366.12 | 238.00 | 494.65 | 2.13 | 27.05 | 70.32 |
| **Total Transport EI of factory 2** | gCO2e/kg | 9.78 | 564.43 | 447.91 | 471.06 | 5.41 | 502.89 | 6.38 | 3.25 | 37.86 |
| **Total Transport EI of factory 3** | gCO2e/kg | 22.27 | 557.80 | 441.28 | 386.68 | 360.24 | 496.26 | 5.53 | 4.33 | 60.58 |

Source of shipping distance: http://ports.com.

On the other hand, transport from factory to farm EI varied from factory to another related to the distances and emission factors for type of transport as shown in Tables 2 and 6.

The maximum transport from factory to farm EI obtained for factory 3 feed with 167.682 $gCO_2e$/kg.feed while the minimum transport from factory to farm EI obtained for factory 1 feed with 5.409 $gCO_2e$/kg.feed.

Table 6. Feed manufacturing EI for different factories and types of feed

| Ration ($gCO_2e$/kg feed) | Electri - city | Diese l | Total energ y EI | Transpo rt EI factory to farm |
|---|---|---|---|---|
| **Feed factory 1 pellet** | 11 | 39 | 51.30 1 | 5.409 |
| **Feed factory 1 extruded** | 45 | 85 | 130.8 2 | 5.409 |
| **Feed factory 2 pellet** | 13 | 29 | 42.96 4 | 62.745 |
| **Feed factory 2 extruded** | 55 | 66 | 122.2 9 | 62.745 |
| **Feed factory 3 pellet** | 12 | 31 | 44.70 5 | 167.682 |
| **Feed factory 3 extruded** | 48 | 74 | 122.4 7 | 167.682 |

Source: survey data analysis.

## Feed packaging EI

Every factory has a different packaging material which has a significant effect on packaging EI. PP, PPT and PP&PE materials used in factories 1, 2 and 3 respectively as showed in Figure 6 and Table 7.

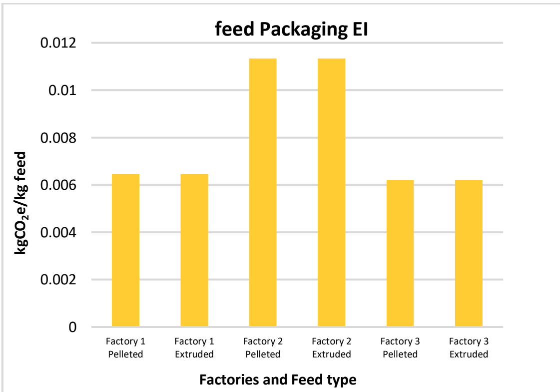



Fig. 6. Feed Packaging EI for different factories and feed types.
Source: Own results.

From Tables 2 and 7, data collected and obtained that maximum packaging EI obtained was 11.64 $gCO_2e$/kg.feed for the second factory and minimum packaging EI obtained was 6.1985 $gCO_2e$/kg.feed for the third factory as declared in Figure 7.

Table 7. Feed packaging consumption and EI.

| | | **Factory 1** | **Factory 2** | **Factory 3** |
|---|---|---|---|---|
| | | Egypt | Egypt | Egypt |
| | Units | Damro | 6th october | Baltim |
| PPT bag | g/bag | 0 | 105 | 0 |
| PP bag | g/bag | 120 | 0 | 0 |
| PP&PE bag | g/bag | 0 | 0 | 115 |
| PPT bag | kgfeed/bag | 0 | 25 | 0 |
| PP bag | kgfeed/bag | 50 | 0 | 0 |
| PP&PE bag | kgfeed/bag | 0 | 0 | 50 |
| PPT bag | ton/year | 0 | 63 | 0 |
| PP bag | ton/year | 10.8 | 0 | 0 |
| PP&PE bag | ton/year | 0 | 0 | 20.7 |
| feed production | ton/y | 4,500 | 15,000 | 9,000 |
| EI | $gCO_2e$/kg feed | 6.456 | 11.34 | 6.1985 |

Source: Own results.

## Secondly, Farming EI

At this stage results obtained showed that Hanafy farm had the maximum EI value compared to Hashim and Aly farm with 3.131, 2.05 and 2.036 kg $CO_2e$/kg.fish, respectively. This was due to high amount of feed used with high value of FCR as indicated in Figure 7.

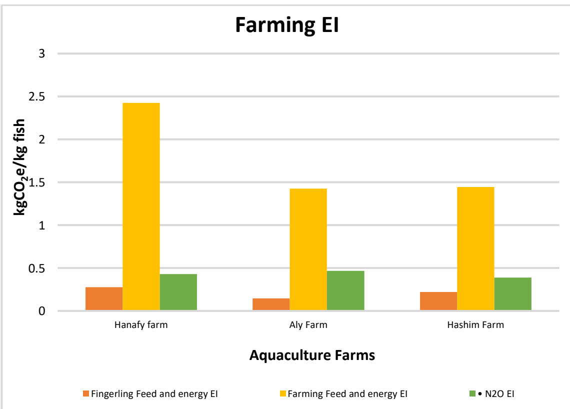



Fig. 7. Farming EI stage parameters
Source: Own results.

As indicated in Figure 8, The highest fingerling feed and energy EI value obtained at Hanafy farm with 0.278 kg $CO_2e$/kg.fish, while the lowest value was at Aly farm with 0.147 kg $CO_2e$/kg.fish.

Hanafy farm had the greatest farming feed and energy EI value of 2.42 kg $CO_2e$/kg.fish, while Aly farm had the lowest value of 1.42 kg $CO_2e$/kg.fish.

Aly farm had the highest $N_2O$ EI value of 0.465 kg $CO_2e$/kg.fish, whereas Hashim farm had the lowest EI value of 0.39 kg $CO_2e$/kg.fish.

Also, bad water quality at the source of Hanafy farm led to more water change and more energy (diesel and petrol) consumption with high EF values as mentioned in Table 2.

While the other farms had sources for electricity and had the abilities for improving water quality by paddle wheel aerators and other sources.

## Fingerling Feed and energy EI

Fingerling Feed and energy EI sub main stage consists of three parameters which are: Fingerling feed, Fingerling diesel and Fingerling electricity.

Fingerling feed had the highest effect on EI at all farms under study followed by fingerling diesel and fingerling electricity, respectively as shown in Figure 8.

Tables 2, 8 and Figure 8 showed that Aly farm had the greatest fingerling electricity EI value of 0.009 kg $CO_2e$/kg.fish, while Hanafy and Hashim farms had the lowest value of 0.0 kg $CO_2e$/kg.fish.

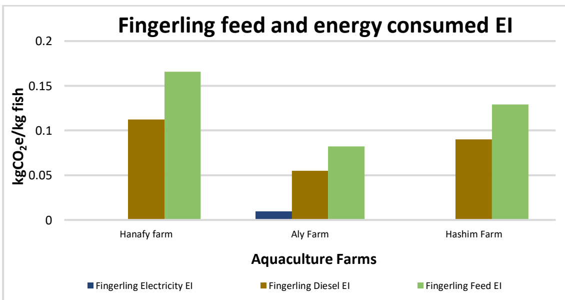



Fig. 8. Fingerling feed and energy consumed EI
Source: Own results.

The highest fingerling diesel EI value was 0.112 kg $CO_2e$/kg.fish at Hanafy farm, while the lowest value was 0.055 kg $CO_2e$/kg.fish at Aly farm.

The greatest fingerling feed EI value was 0.166 kg $CO_2e$/kg.fish at Hanafy farm, while the lowest EI value was 0.08 kg $CO_2e$/kg.fish in Aly farm.

Table 8. Fingerling feed and energy consumed EI

| | | Unit | Hanafy Farm | Aly Farm | Hashim Farm |
|---|---|---|---|---|---|
| fingerling number | | n | 63,000 | 120,750 | 78,750 |
| fingerling weight | | kg | 0.015 | 0.04 | 0.03 |
| total fingerling weight | | kg | 945 | 4,830 | 2,362.5 |
| Feed | | kg/season | 150 | 350 | 250 |
| Electricity | | MJ/season | 0 | 360 | 0 |
| Diesel | | MJ/season | 1,412 | 3,530 | 2,824 |
| Feed | pellet | $kgCO_2e$/season | 156.675 | 220.266 | 241.106 |
| | extruded | $kgCO_2e$/season | 0 | 177.099 | 64.165 |
| Electricity | | $kgCO_2e$/season | 0 | 45.8 | 0 |
| Diesel | | $kgCO_2e$/season | 106.268 | 265.671 | 212.536 |
| Feed EI | | $kgCO_2e$/kg | 0.165 | 0.082 | 0.129 |
| Electricity EI | | $kgCO_2e$/kg | 0 | 0.009 | 0 |
| Diesel EI | | $kgCO_2e$/kg | 0.112 | 0.055 | 0.089 |
| Total EI | | $kgCO_2e$/kg | 0.278 | 0.146 | 0.219 |

Source: Own results.

**Farming Feed and energy EI**

Farming petrol, farming diesel, farming electricity and farming feed are the four parameters that constitute the Feeding and energy for farming EI sub main stage.

As demonstrated in Figure 10, farming feed had the greatest impact on EI across all farms studied. Tables 2, 9, 10, 11 and Figure 9 showed that Hanafy farm had the highest farming petrol EI value of 0.071 kg $CO_2$e/kg.fish.

While Hashim farm had the lowest value of 0.0256 kg $CO_2$e/kg.fish. Hanafy farm had the highest farming diesel EI value of 0.68 kg $CO_2$e/kg.fish, while Hashim farm had the lowest value of 0.053 kg $CO_2$e/kg.fish. Hashim farm had the highest farming electricity EI value of 0.101 $kgCO_2$e/kg.fish, while Hanafy farm had the lowest value of 0.0 kg $CO_2$e/kg.fish.

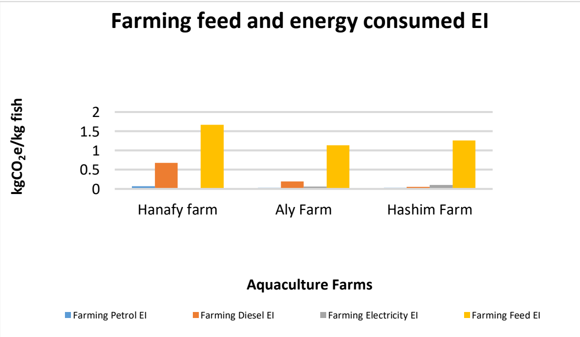



Fig. 9. Farming feed and energy EI
Source: Own results.

At Hanafy farm, the highest EI value for farming feed was 1.67 kg $CO_2$e/kg.fish, while the lowest EI value was 1.137 for Aly farm.

$N_2O$ EI $N_2O$ EI sub main stage consists of farming feed $N_2O$ and fingerling feed $N_2O$.

Farming feed $N_2O$ had the biggest impact on EI across all studied farms, as shown in Figure 10. Aly farm had the highest $N_2O$ EI value of 0.465 kg $CO_2$e/kg.fish, while Hashim farm had the lowest value of 0.39 kg $CO_2$e/kg.fish, as shown in Tables 2 and 12 and Figure 10. The maximum fingerling feed EI value was 0.04 kg $CO_2$e/kg.fish at Hanafy farm, while the lowest value was 0.018 kg $CO_2$e/kg.fish at Hashim farm.

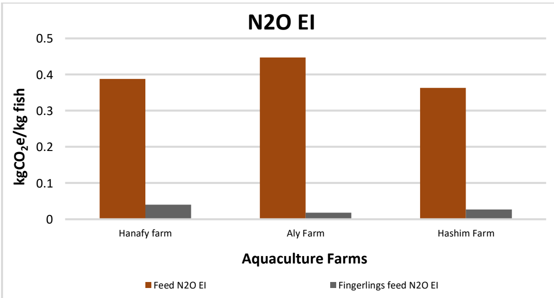



Fig. 10. Farming and fingerling $N_2O$ EI.
Source: Own results.

Aly farm had the highest farming feed $N_2O$ EI value of 0.447 kg $CO_2$e/kg.fish, while Hashim farm had the lowest value of 0.363 kg $CO_2$e/kg.fish, as shown in Tables 2 and 12 and Figure 10.

Table 9. Study area, farm and species specification

| No | Item | Unit | Hanafy Farm | Aly Farm | Hashim Farm |
|---|---|---|---|---|---|
| 1 | Governorate and town | n | Kafrelshikh, sidy salim | Elbehira, Edko | Eldakahlia, Belqas |
| 2 | Ccoordinates | n | 31°22'58.9"N 30°47'20.8"E | 31°17'00.1"N 30°16'12.7"E | 31°26'18.3"N 31°25'11.2"E |
| 3 | Area | $m^2$ | 42,000 | 96,600 | 63,000 |
| 4 | Water depth | m | 1.5 | 1.25 | 1.25 |
| 5 | Water volume | $m^3$ | 63,000 | 120,750 | 78,750 |
| 6 | Aquaculture density | Fish/$m^3$ | 5 | 4 | 5 |
| 7 | Fish quantity | Fish/Farm | 315,000 | 483,000 | 393,750 |
| 8 | Species and ratio | Tilapia | 70 | 80 | 90 |
| | | Mugiliade | 25 | 17 | 9 |
| | | Carp | 5 | 3 | - |
| | | Catfish | - | - | 1 |

Source: Own results.

Table 10. Estimation of FCR and consumed feed

| | | Hanafy Farm | Aly Farm | Hashim Farm |
|---|---|---|---|---|
| Survival | % | 90 | 70 | 85 |
| Season | Days | 190 | 175 | 170 |
| fingerlings weight | kg | 0.015 | 0.03 | 0.04 |
| Average harvest weight | kg | 0.29 | 0.27 | 0.3 |
| Total harvest per year | t/y | 15.5925 | 20.286 | 17.40375 |
| Total feed per year | t/y | 23.857 | 35.703 | 24.887 |
| FCR | Kg feed/ kg fish | 1.53 | 1.759 | 1.429 |
| Harvest per area | kg/$m^2$ | 0.37 | 0.21 | 0.276 |
| Feed Type, ratio | Pellet | 0.4 | 0.55 | 0.25 |
| | Extruder | 0.6 | 0.45 | 0.75 |
| Feed Type, t/y | Pellet | 9.543 | 19.637 | 6.222 |
| | Extruder | 14.314 | 16.067 | 18.665 |

Source: Own results.

Table 11. EI for feed and consumed energy

| | | **Hanafy Farm** | **Aly Farm** | **Hashim Farm** |
|---|---|---|---|---|
| **Diesel** | l/year | 4,000 | 1,500 | 350 |
| **Petrol** | l/year | 500 | 250 | 200 |
| **Electricity** | kW/year | 0 | 2800 | 3850 |
| **Diesel** | l/kg | 0.257 | 0.074 | 0.02 |
| **Petrol** | l/kg | 0.032 | 0.012 | 0.015 |
| **Electricity** | kW/kg | 0 | 0.138 | 0.221 |
| **EI, Pellet** | kg $Co_2e$/year | 9.967 | 21.626 | 7.500 |
| **EI, Extruder** | kg $Co_2e$/year | 16.089 | 18.968 | 23.953 |
| **Total feed EI** | **kg $Co_2e$/kg fish** | **1.671** | **1.137** | **1.264** |
| **Diesel** | kg $Co_2e$/kg fish | 0.682 | 0.196 | 0.053 |
| **Petrol** | kg $Co_2e$/kg fish | 0.072 | 0.027 | 0.026 |
| **Electricity** | kg $Co_2e$/kg fish | 0 | 0.063 | 0.101 |
| **Total Energy EI** | **kg $Co_2e$/kg fish** | **0.753** | **0.287** | **0.181** |

Source: Own results.

Table 12. $N_2O$ emissions calculation

| | | Hanafy Farm | Aly Farm | Hashim Farm |
|---|---|---|---|---|
| **Kg Feed/ton fish** | | 1,530 | 1,759.982 | 1,429.979 |
| **kg of N in feed /t fish** | Kg N feed/t fish | 60.05 | 69.077 | 56.125 |
| **N content of fish** | kgN/t fish | 13.944 | 16.039 | 13.032 |
| **kg of N excreted per t of fish** | kgN/t fish | 46.106 | 53.037 | 43.093 |
| **$kgN_2O$-N/t fish** | $kgN_2O$-N/t fish | 0.829 | 0.954 | 0.776 |
| **$kgN_2O$/t of fish** | $kgN_2O$/t fish | 1.304 | 1.5 | 1.218 |
| **Emission of kg $N_2O$/kg of fish** | $kgCO_2e$/kg fish | 0.388 | 0.447 | 0.363 |
| **Fingerling emissions** | $kgCO_2e$/kg fish | 0.0403 | 0.018 | 0.027 |
| **Total $N_2O$** | $kgCO_2e$/kg fish | 0.429 | 0.465 | 0.39 |

Source: Own results.

## Thirdly, Post-farming EI

At this stage, the data revealed that Aly farm had the highest EI value, with 0.222 kg $CO_2e$/kg.fish, while Hashim and Hanafy farms EI values were 0.18 and 0.13 kg $CO_2e$/kg.fish, respectively as shown in Figure 11.

This was owing to the large distance of transport fishes to markets compared to others. As shown in Figure 11, Hashim farm had the greatest ice manufacturing energy EI value of 0.0079 kg $CO_2e$/kg.fish, while Hanafy farm had the lowest value of 0.0035 kg $CO_2e$/kg.fish.

The highest transport to markets EI value was 0.218 kg $CO_2e$/kg.fish for Aly farm while the lowest value was 0.13 kg $CO_2e$/kg.fish for Hanafy farm.

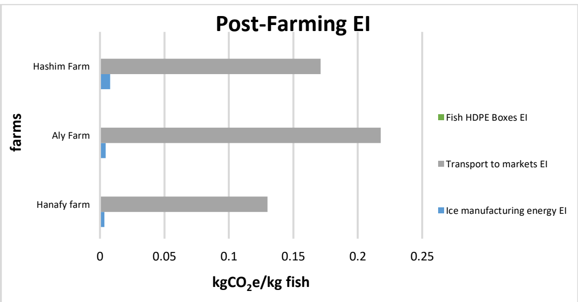



Fig. 11. Post-farming stage parameters
Source: Own results.

## Fish HDPE Boxes EI

From table 2 and survey conducted that all the three farms had the same value for fish HDPE Boxes EI with 0.00063 kg.$CO_2e$/kg.fish which were 1kg HDPE boxes and capacity of 25 kg fish for 200 times use.

Table 13. Ice manufacturing energy EI calculation

| | unit | Hanafy Farm | Aly Farm | Hashim Farm |
|---|---|---|---|---|
| Ice use | ton | 2 | 3.2 | 5 |
| Electricity use | kw | 116 | 185.6 | 290 |
| Diesel use | kg | 0.5 | 0.8 | 1.25 |
| Electricity EI | $kgCO_2e$/ kg fish | 0.0034 | 0.00419 | 0.0076 |
| Diesel EI | $kgCO_2e$/ kg fish | 0.0001 | 0.00013 | 0.000235 |
| Total EI | $kgCO_2e$/ kg fish | 0.0035 | 0.0043 | 0.0079 |

Source: Own results.

## Ice manufacturing energy EI

Ice manufacturing electricity and ice manufacturing diesel are the two parameters that make up the ice manufacturing energy EI sub main stage.

As demonstrated in Tables 2 and 13 and Figure 12, Ice manufacturing electricity had the greatest impact on EI across all farms studied.

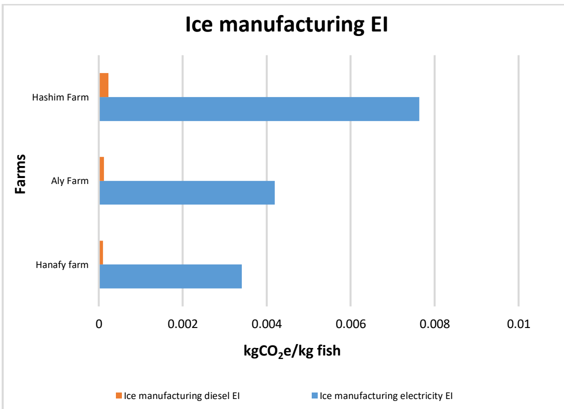



Fig. 12. Ice manufacturing energy EI
Source: Own results.

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Hashim farm had the highest ice manufacturing EI value of 0.0079 kg $CO_2$e/kg.fish, while Hanafy farm had the lowest value of 0.0035 kg $CO_2$e/kg.fish as shown in Figure 12.

**Transport to markets EI**

As indicated in Tables 2 and Figure 13, the EI of conveying fishes to markets consists of transporting to small markets EI, transporting to medium markets EI and transporting to large markets EI.

Also, transporting to medium markets had the greatest impact on EI across all farms under study.

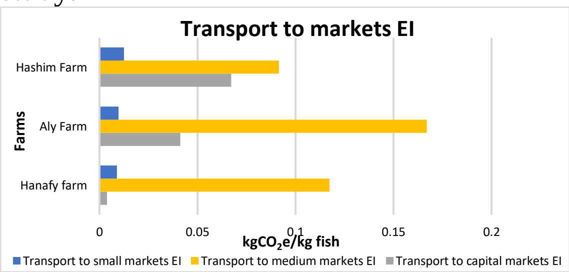


Fig. 13. Transport to markets EI
Source: Own results.

The highest EI for transporting to medium markets was 0.16 kg.$CO_2$e/kg fish for Aly farm, and the minimum EI for shipping was 0.09 kg.$CO_2$e/kg for Hashim farm.

While, 0.067 and 0.041 kg.$CO_2$e/kg fish were the highest and lowest transporting to capital markets EI for Hashim and Aly farms, respectively.

**Total EI**

Table 14 and Figure 14 indicated that the main parameters (Fingerling, Feed, $N_2O$, Energy on farm, Transport to markets, Ice consumption and Fish HDPE Boxes) and sub main (Farming Petrol EI, Farming diesel EI, Farming Electricity EI, Farming Feed EI, Fingerling Electricity EI, Fingerling Diesel EI, Fingerling Feed EI, Feed $N_2O$ EI, Ice manufacturing electricity EI, Ice manufacturing diesel EI, Transport to capital markets EI, Transport to medium markets EI, Transport to small markets EI, Fish HDPE Boxes EI and Fingerlings feed $N_2O$ EI) parameters contributing in LCA and carbon foot print.

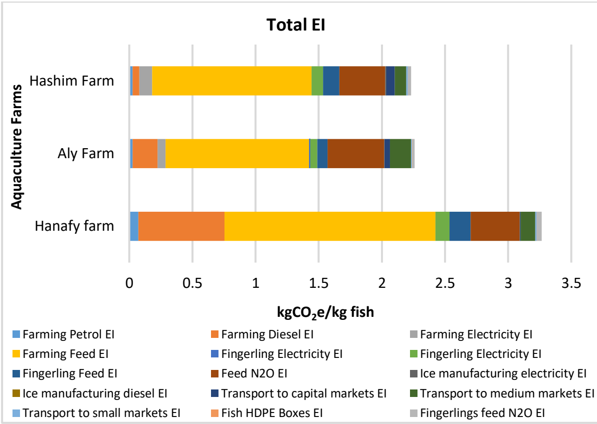


Fig. 14. Total EI parameters.
Source: Own results.

Farming feed parameter had the highest EI percentage at total EI for all farms under study with 51.8, 50.33 and 56.6% for Hanafy, Aly and Hashim farms, respectively.

While, ice manufacturing diesel had the lowest EI percentage at total EI for all farms under study with 0.003, 0.005 and 0.01% for Hanafy, Aly and Hashim farms, respectively.

Hanafy farm had the highest EI value of 3.265 kg.$CO_2$e/kg fish and 50.917ton $CO_2$e/season compared with Hashim farm which had the lowest EI value with 2.23 kg.$CO_2$e/kg fish and 38.86 ton $CO_2$e/season as shown in Table 14 and Figure 14.

Table 14. Total EI for the three farms

| | | **Hanafy Farm** | **Aly Farm** | **Hashim Farm** |
|---|---|---|---|---|
| Fingerling | Kg.$CO_2$e/kg fish | 0.278 | 0.146 | 0.219 |
| Feed | Kg.$CO_2$e/kg fish | 1.671 | 1.137 | 1.263 |
| $N_2O$ | Kg.$CO_2$e/kg fish | 0.429 | 0.465 | 0.39 |
| Energy on farm | Kg.$CO_2$e/kg fish | 0.752 | 0.287 | 0.18 |
| Transport to markets | Kg.$CO_2$e/kg fish | 0.13 | 0.217 | 0.171 |
| Ice consumption | Kg.$CO_2$e/kg fish | 0.0035 | 0.0043 | 0.0079 |
| Fish HDPE Boxes | Kg.$CO_2$e/kg fish | 0.0006 | 0.0006 | 0.0006 |
| Total EI per kg fish | Kg.$CO_2$e/kg fish | **3.265** | **2.259** | **2.233** |
| Total EI per season | Ton.$CO_2$e/Season | **50.917** | **45.829** | **38.864** |

Source: Own results.

# CONCLUSIONS

As Egypt from the most countries vulnerable to global warming, estimating carbon footprints in aquaculture farms is a crucial topic. As a result, this study focuses on the LCA of semi-intensive aquaculture in Egypt. Hanafy farm had the greatest EI value, with 3.265 kg.$CO_2$e/kg fish and 50.917 tonne $CO_2$.e/season, while Hashim farm had the lowest, with 2.23 kg.$CO_2$e/kg fish and 38.86ton $CO_2$.e/season.

Also, for all farms under research, the farming feed parameter had the greatest EI percentage at total EI, with 51.8, 50.33, and 56.6 percent for Hanafy, Aly, and Hashim farms, respectively. While, ice manufacturing diesel of 0.003, 0.005, and 0.01 percent for Hanafy, Aly, and Hashim farms, respectively had the lowest EI percentage at total EI for all farms under study.

Finally, more research is needed to reduce GHG sources and optimize techniques that reduce emissions across all LCA.

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# USING RUBBER TUBES TO GENERATE MICRO BUBBLES FOR AERATION SYSTEM IN SEMI-INTENSIVE FISH FARMING

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***Abstract***

*The expansion of aquaculture ponds necessitates the development of aeration and the addition of oxygen. Rubber tubes are a new way of aerating by generating micro bubbles on the water surface. Experiments were conducted to investigate and determine the effects of air flow rate, tube wall thickness, depth from the surface and design shape on saturation time, the oxygen mass transfer coefficient and standard aeration efficiency. To identify each indicator, testing were carried out in accordance with ASCE 2007 guidelines from the American Society of Civil Engineers. The findings demonstrated a connection between oxygen mass transfer coefficient and operational parameters were as follows: inverse relationship with air flow rate, inverse relationship with depth from water surface, positive relationship with tube wall thickness and increases with circular shape design more than longitudinal. The maximum value of standard aeration efficiency was 2.66 kg.$O_2$/kW.h under operational parameters of 0.1 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from the water surface, 7 mm for tube wall thickness and circular design shape. The minimum value of saturation time was 8 minutes under operational parameters of 0.1 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from the water surface, 7 mm for tube wall thickness and circular design shape.*

***Key words***: *aquaculture, water quality, dissolved oxygen, aeration diffusion by fine bubbles*

## INTRODUCTION

The quantity of fish produced increased by 5.4% to 2.0 million tonnes in 2019 from 1.90 million tonnes in 2018, mainly because more fish and rice fields were produced on farms. Lakes came in second with a production percentage of 79.7%, followed by marine waters with 4.9%, fresh water with 3.8%, and rice fields with 0.8% of the total amount of fish produced [5].

Egypt uses a variety of aquaculture techniques, such as circular tanks, dug earthen ponds, pens and enclosures, concrete and raceway ponds, and floating fish cages, among others. Additionally, semi-intensive clay pond aquaculture is the most common aquaculture practice in Egypt. Based on agricultural drainage waters, intense aquaculture farming has increased during the past 15 years, particularly in the deserts of northern Sinai [11].

Brackish water produced 855,789 t of tilapia in 2017, accounting for 70% of all tilapia produced in Africa. Egypt dominates the production of farmed tilapia in Africa. In 2017, the total amount of farmed tilapia produced in Africa was 79% (967,301 t), with Egypt producing the majority of that amount. Africa's contribution to the world's tilapia output will drop from 21% in 2017 to only 4.3% if Egypt's share is discounted. In Egypt, brackish water settings in the northern lakes regions along the Mediterranean coast are mostly used for tilapia culture. Egypt produced 854,808 t of tilapia from brackish water sources in 2017, accounting for 88.4% of the nation's overall (and 70% of the continent's) tilapia production [7].

Farmers must monitor water quality in order to spot trends in concentration changes and modify their management strategies accordingly. Numerous characteristics of water are connected and interact with one another, and changes in one variable might provide light on changes in another related one [20].

Due to the small amount of gill surface area that can absorb oxygen, the rate at which oxygen can be taken up is constrained, and sub-optimal DO concentrations slow down fish growth rates, the concentrations of DO in water are crucial. Also, mentioned that male Nile tilapia of the two size classes-large fish (>200 g) and little fish (100 g)-were studied to determine the effects of DO on feed intake and nitrogen and energy balances. On the other hand, larger fish had higher feed consumption when DO rose from 2.6 to 6.0 mg. $L^{-1}$, and the initial DO for these fish was around 5.5 mg. $L^{-1}$. As DO decreased, the fish tended to need less energy for upkeep. Gross energy consumption values, edible energy intake and metabolized energy intake were significantly increased for large fish as DO levels rose from 1.6 to 6.1 mg.$L^{-1}$ [18].

More oxygen may dissolve in water when the temperature is lower. The application noted that water at a temperature of 32°C can contain up to 7.3 mg/l of oxygen, whereas water at a temperature of 7°C can hold 12.1 mg/l. Low oxygen levels will result from rising water temperatures. The dissolved oxygen levels at a given site are often larger in the winter than they are in the summer for this cause [13].

Dissolved oxygen is the amount of free, non-compound oxygen that is present in water or other liquids. It is a significant aspect in determining the water quality because of its effect on the aquatic life present in a body of water. After water, dissolved oxygen is the most crucial element in limnology which means the study of lakes. Aquatic life can be harmed and the quality of the water can be altered by too much or too little dissolved oxygen [12].

The minimum dissolved oxygen ranges for Oreochromis niloticus were 0.1-0.5 mg/l, while the best value was between 6 and 6.5 mg/l [1].

The most crucial period to introduce more aeration is shortly before dawn, when DO concentrations are often lowest because this is when they frequently drop below tolerable levels. Early morning DO for warmwater fish should stay above 3–4 mg/L, and above 5–6 mg/L for coldwater fish. Warmwater and coldwater fish, respectively, can survive with concentrations as low as 1.0-1.5 mg/L and 2.5-3.5 mg/L. However, these concentrations can raise stress, reduce appetite or aggression to eat, and - if low enough for a long length of time - they can be deadly [4].

Due to the local fish's higher metabolic rates while they are feeding, DO drops during feeding. Fish spend more energy to eat in a competitive manner, which causes an increase in metabolic rate. A DO requirement is also produced by uneaten feed and feces. This excrement provides plant nutrients that encourage the growth of phytoplankton. When phytoplankton is more abundant, the amount of DO that they need to breathe at night can increase. To raise the need for DO, phytoplankton are also continuously perishing and decomposing. The use of fertilizer can encourage the growth of algae, which can improve oxygen production and remove potentially hazardous ammonia [21].

The performance of tilapia may be significantly impacted by the interplay between diet mix and DO concentration. These researchers fed Nile tilapia (35 g) two different diets at two different oxygen saturation levels: normoxia (100%, 6.9 mg.$L^{-1}$) and hypoxia (50%, 3.5 mg.$L^{-1}$). The control diet was based on fishmeal (FM), while the other diet was based on soybean meal (SBM). Under normoxia, the FM "control" diet resulted in the highest growth rates [19].

The daily rate of partial water exchange in clay ponds is relatively low. In fact, early in the season, when the number of fish is minimal and well below the pond's carrying capacity, it might not even be necessary. However, as fish get bigger and bigger, there is a greater need for freshwater. Based on the stocking density, fish size, and species, it may reach 20% or more every day by the end of the season [14].

In the aquatic environment, direct diffusion from the air, wind wave action, and photosynthesis by aquatic plants are the three main sources of oxygen. When the water quality is good, oxygen molecules easily infiltrate the water until the oxygen volume is balanced. If the atmosphere's dissolved oxygen concentration is higher than concentration in the water, which tends to diffuse in the air, the same thing could occur, but in the other direction [9].

The three essential parts of a diffused aeration system are an air pump, a diffuser, and connective tubing. Diffusers offer a variety of forms, including those with coarse, medium, and fine pore sizes. According to estimates, coarse, medium, and fine pore diffusers all function between 0.60 and 1.20 kg $O_2$/kW/hr, 1.0 to 1.6 kg $O_2$/kW/hr, and 1.2 to 2.0 kg $O_2$/kW/hr, respectively. Larger bubbles are produced by coarse pore diffusers, while smaller bubbles are produced by fine pore diffusers. Fouling and scaling, which are biological and chemical processes that damage diffuser functioning, can occur in diffusers. This necessitates periodic hydrochloric acid cleaning of diffusers [15].

The main aims of the research were:

-Evaluating fine bubbles tube aeration performance.

-Selecting the optimum operational conditions.

## MATERIALS AND METHODS

### Experimental setup

The experiment was established in an aquaculture private pond at Kafrelshikh government, Egypt. As indicated at figure 1, 2, 3 and table 1 stainless-steel tank with dimensions of 1×1×1 (m) for length, width and height, respectively used as water reservoir. The tank was filled up with 1 $m^3$ of tap water. An electric single phase compressor model APT (SGBM9037) of 1.5 hp, 25 L capacity, maximum pressure of 8 bar and maximum free air delivery:130 $L.min^{-1}$ used as a source of air injection. Three models of diffusion tubes D25-4, D25-6 and D25-7 which made from rubber and 1 m length for airmmax company, China with specification indicated in Table 1. Portable Galvanic Dissolved Oxygen Meter model HI9147 for HANNA company, USA used for estimation dissolved oxygen, water temperature and water salinity. Digital LCD anemometer and thermometer for measuring air wind speed and temperature. Digital vernier calliper of model SM-453, Japan used for estimating dimensions and diameters of experimental parts. Watt meter to estimate consumed energy in kW.h.

### Experimental procedure

Main experiment established to evaluate rubber tube bubbles aeration method. Performance indicators estimated were: (1) Saturation time (2) $K_La_{20}$ (3) SAE. According to (ASCE, 2007) tap water used in the experiment and changed after treatment. Deoxygenation of water attempted by adding 0.1 $mg.L^{-1}$ cobalt chloride ($CoCl.6H_20$) and 10-12 $mg.L^{-1}$ sodium sulfite ($NaSO_3$) for every $mg.L^{-1}$ of dissolved oxygen. Dissolved oxygen probe preferred to be at middle of the tank, and at least 20 cm from tank sides, surface and aeration equipment. Measuring process starts at the point of DO reads increase from zero concentrations and previous time neglected. Readings are recorded till reaching 80-85% of dissolved oxygen saturation concentration.

### Theoretical considerations

The dissolved oxygen ($C_e$) concentrations at saturation are estimated using the following equation [17]:

$$C_e = \frac{125.9}{(32+1.8\,T)^{0.625}} \qquad eq\ (\mathbf{III.1})\ldots\ldots(1)$$

where:

$C_e$ = Saturation concentration of oxygen, mg/L at atmospheric pressure;

T = Water temperature, °C.

When a force is created, mass transfer by diffusion happens between the two points. The relative pressure gradient drives the gas phase, whereas the concentration gradient drives the water phase. The formula for oxygen transfer [8] is as follows:

$$\frac{dm}{dt} = -D_l \times A\frac{dc}{dy} \qquad eq\ (\mathbf{III.2})\ldots\ldots(2)$$

where:

$\frac{dm}{dt}$ is the proportion of diffusion mass transfer,

DL is the oxygen molecular diffusion in water coefficient,

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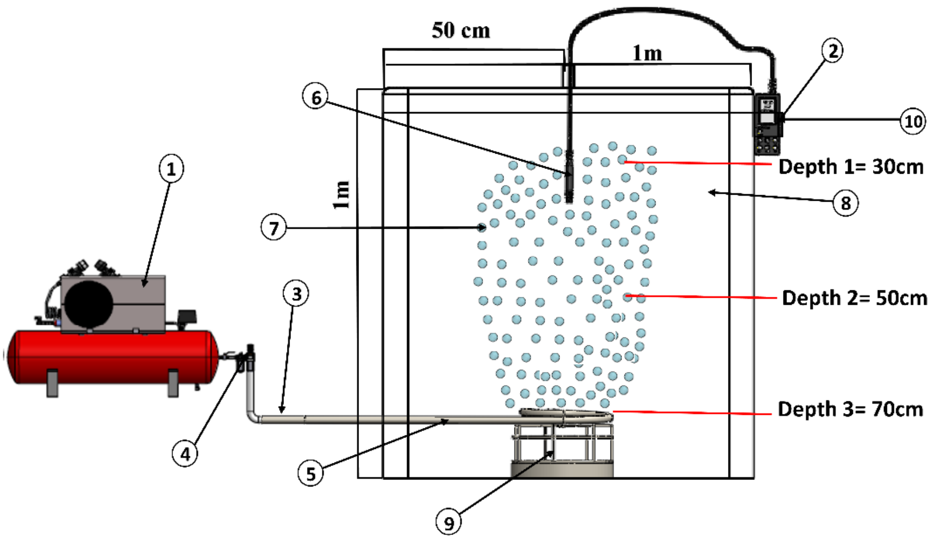
A is the diffusion cross sectional area and expressed as $m^2/s$, and $\frac{dc}{dy}$ is the oxygen concentration gradient perpendicular to the cross-sectional area and mentioned by $kg/m^3/m$.

So, the above equation could mention as:

$$\frac{dm}{dt} = -D_g \times A\left[\frac{dc}{dy}\right]_g = -D_l \times A\left[\frac{dc}{dy}\right]_l = -D_e \times A\left[\frac{dc}{dy}\right]_e \qquad eq\ (\mathbf{III.3})..(3)$$

where:

where, $\left[\frac{dc}{dy}\right]_g$ is the concentration inclination in gas layer, $\left[\frac{dc}{dy}\right]_l$ is the concentration gradient in Water layer, $\left[\frac{dc}{dy}\right]_e$ is the concentration inclination in the body of the Water, $D_g$ is the coefficient molecular diffusion of oxygen in gas medium and $D_e$ is the eddy diffusion coefficient of the oxygen in the medium of the Water.




| NO | ITEM |
|---|---|
| 1 | Air Compressor |
| 2 | Dissolved Oxygen Meter |
| 3 | Air Compressor Tube |
| 4 | Air flow valve |
| 5 | Tube |
| 6 | Sensor |
| 7 | Bubbles |
| 8 | Tap Water |
| 9 | Tube Holder |
| 10 | Dissolved Oxygen Meter Holder |

Fig. 1. Schematic diagram of the experiment.
Authors' drawing.

Table 1. Specification of different tubes models under study

| Item \ Model | Unit | D25-4 | D25-6 | D25-7 |
|---|---|---|---|---|
| Outer diameter (OD) | mm | 25 | 25 | 25 |
| Inner diameter (ID) | mm | 16 | 13 | 11 |
| Wall thickness (Wall) | mm | 4 | 6 | 7 |

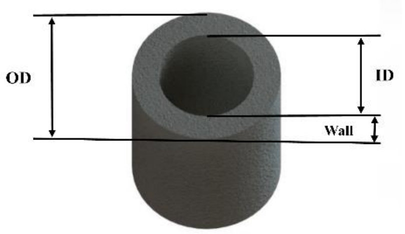
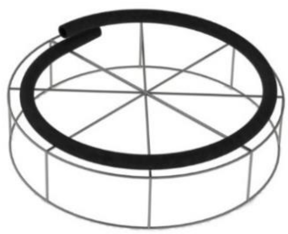



Fig. 2. Schematic diagram of rubber tube and its parts.
Source: Authors' drawing.

a) Longitudinal shape



b) Circular shape

Fig. 3. Design shapes of diffusion tubes.
Source: Authors' drawing.

This Equation might be as:

$$\frac{dm}{dt} = \frac{D_L}{y_L} A \times \Delta C = K_L = A \times \Delta C \qquad eq\ (\mathbf{III.4})...(4)$$

where:
$Y_L$ is the thickness of Water layer,
$\Delta C$ is shortage of oxygen = $C^* - C$, $C^*$ is equivalent concentration at the surface, and C is the concentration in the water state. $K_L = \frac{D_L}{y_L}$ and $K_L$ is identified as the water layer coefficient. Previous equation can be stated in concentration by volume, V, of the water:

$$\frac{1}{V} \times \frac{dm}{dt} = \frac{dc}{dy} = K_L \times \frac{A}{V} \times \Delta C \qquad eq\ (\mathbf{III.5}) .......(5).$$

In non-natural aeration methods, it is very difficult to estimate the interfacial area because of the turbulent surface. Hence $K_L \frac{A}{V}$ is substituted by coefficient transfer $K_{La}$ of the method, and its units is $h^{-1}$. Therefore, previous equation shows $K_{La}$ as:

$$\frac{dc}{dt} = K_L \times a_T \times \Delta Cz = K_L \times a_T \times (C^* - C) \qquad eq\ (\mathbf{III.6}) ....(6)$$

Accumulation of $K_L$ and $a_T$, $K_L a_T$ a generated expression is used as the overall coefficient of oxygen transfer. By integrating previous equation for C among $C_0$ and $C_t$ and t = 0 to t, the following terminologies are obtained.

$$\ln \frac{C^* - C_t}{C^* - C_0} = K_L \times a_T \times (t - t_0) \qquad eq\ (\mathbf{III.7}) ....(7)$$

$$C_t = C^* - (C^* - C_0) exp[-K_L \times a_T \times (t - t_0)] \qquad eq\ (\mathbf{III.8}) ..(8)$$

where:
$K_L a_T$ is the coefficient of overall oxygen transfer ($h^{-1}$),
$C_0$ is the start concentration of oxygen in sample (mg/L),
$C_t$ is the water concentration of oxygen in end at time t (mg/L) and
($C^* - C_0$) is the oxygen loss (mg/L).
According to the ASCE Method, the coefficient of overall oxygen transfer ($K_L a_T$) of previous equation can be estimated by the Nonlinear Regression Method. Previous equation was used to calculate the three variables, $C^*$, $C_0$, and $K_L a_T$ [16].
At standard conditions of temperature (20°C), $K_L a_t$ was calculated:

$$K_L \times a_{20} = \frac{K_L \times a_T}{\theta^{(T-20)}} \qquad eq\ (\mathbf{III.9}) ...(9)$$

where:
$\theta$ means correction factor of temperature ($\theta$ = 1.024 for tap water) [6].
By using dissolved oxygen drop the oxygen transfer rate (OTR) of aeration device is definite as the quantity of oxygen mass that the tool added into water at specified time [2].

$$OTR = K_L a_T \times \Delta C \times V \qquad eq\ (\mathbf{III.10}) ....(10)$$

where:
$\Delta C$, the difference between $C^*$ and $C_0$, V is the quantity of water in trial tank ($m^3$), for typical conditions at 20°C the rate of oxygen transfer (OTR) mentioned as:

$$OTR = K_L a_{20} \times \Delta C \times V \qquad eq\ (\mathbf{III.11}) ....(11).$$

In case of evaluation under standard conditions of water temperature = 20°C, start DO = 0 mg/L, atmospheric pressure = 1atm and pure tap water) /$h^{-1}$ [2], hence this terminology express the standard oxygen transfer rate (SOTR) as follow:

$$SOTR = (K_L a)_{20} \times \Delta C \times V \qquad eq\ (\mathbf{III.12}) ....(12).$$

The standard oxygen transfer rate (SOTR), which is used to compare various aeration equipment, is used to determine which is better. The formula for the actual oxygen transfer rate ($OTR_f$) is given as follow [3]:

$$OTR_f = \frac{SOTR[\propto \times \theta^{T-20}(\beta C_s - C_p)]}{9.07} \qquad eq\ (\mathbf{III.13}) ........(13).$$

The quantity of oxygen transmitted (kg) per requested power, or standard aeration efficiency, is the optimum metric for evaluating different oxygenation techniques. Use the following equation to determine SAE:

$$SAE = \frac{SOTR}{P} \qquad eq\ (\mathbf{III.14}) ........(14)$$

where:
P is the required power by the aerator under operating conditions (kW).
**Variables under study were:** permissible limits for operational parameters at aquaculture earthen ponds were: (1) three air flow ranges (0.554, 0.969 and 1.246 $m^3.h^{-1}$), (2) three depths from water surface (0.3, 0.5 and 0.7 m), (3) three tube wall thickness (4, 6

and 7 mm), (4) two design shapes (longitudinal and circular) [10].

## RESULTS AND DISSCUSIONS

**Effect of aeration by fine bubbles on oxygen productivity**

**Effect of aeration by fine bubbles on saturation time**

Figures show the effect of air flow rate, depth from the surface, thickness of tube wall and design shape on saturation time as shown in Figures 4, 5 and 6. Under operational conditions of 1.246 $m^3.h^{-1}$ air flow rate, 0.30 m depth from water surface, 4 mm tube wall thickness, and longitudinal design shape, the highest value of saturation time was 22 minutes.

The lowest value of saturation time was 8 minutes under operational parameters of 0.554 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from water surface, 7 mm for tube wall thickness and circular design shape.

***a) The effect of air flow quantity on saturation time***

The rise of air flow rate from 0.556 to 1.246 $m^3. h^{-1}$ leaded to increase at saturation time with 66 % (from 12 to 20 minutes) at depth from water surface of 30 mm, tube wall thickness of 4 mm and circular design shape as shown in Figures 4, 5 and 6.

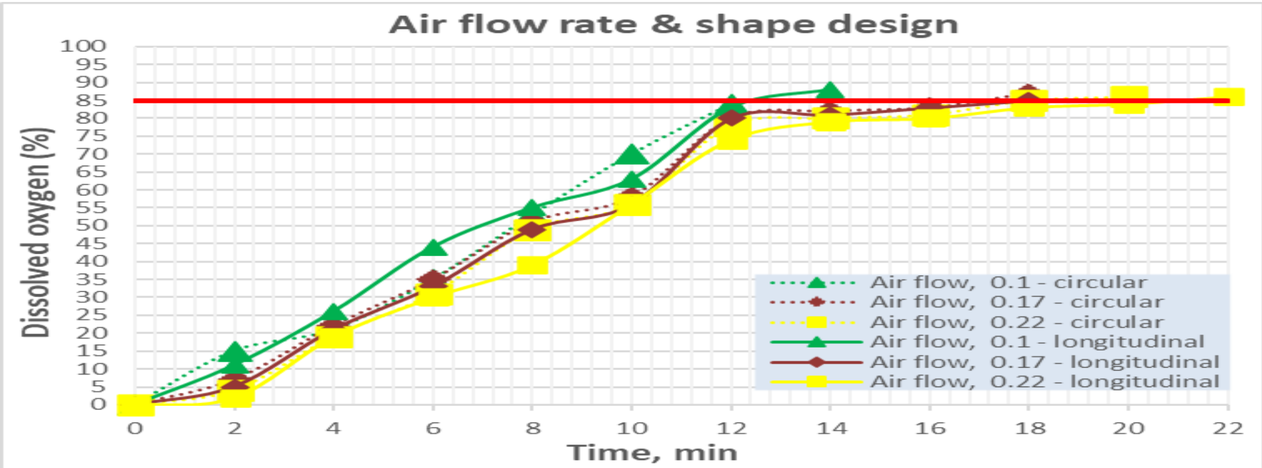



Fig. 4. The impact of air flow rate and shape design on saturation time at a wall thickness of 4 mm and a depth of 0.3 m. Source: Authors' determination.

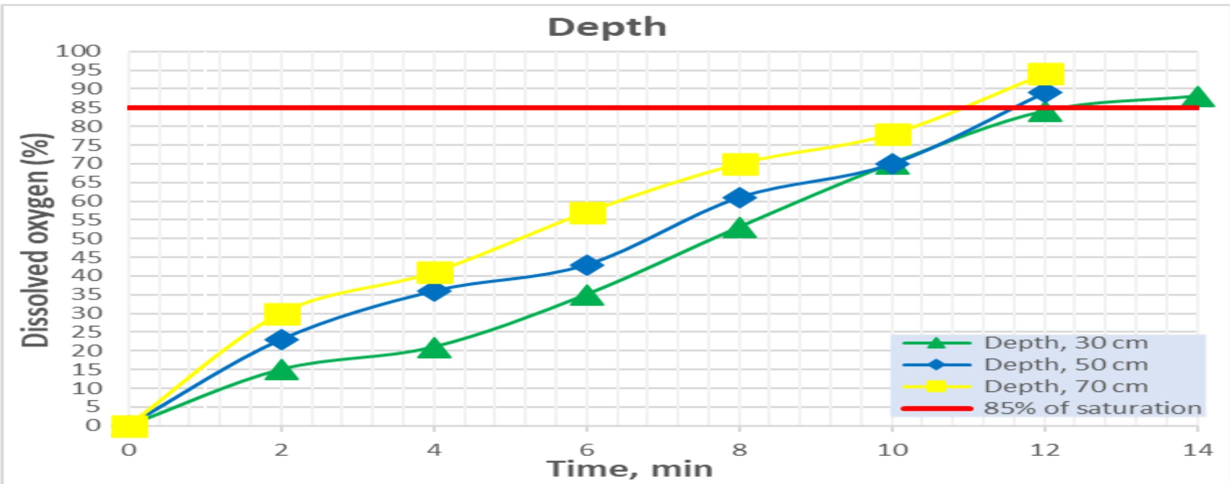



Fig. 5. Impact of diffusion tube submergence on saturation time for 0.554 $m^3.h^{-1}$ air flow rate and circular form design and 4 mm wall thickness
Source: Authors' determination.

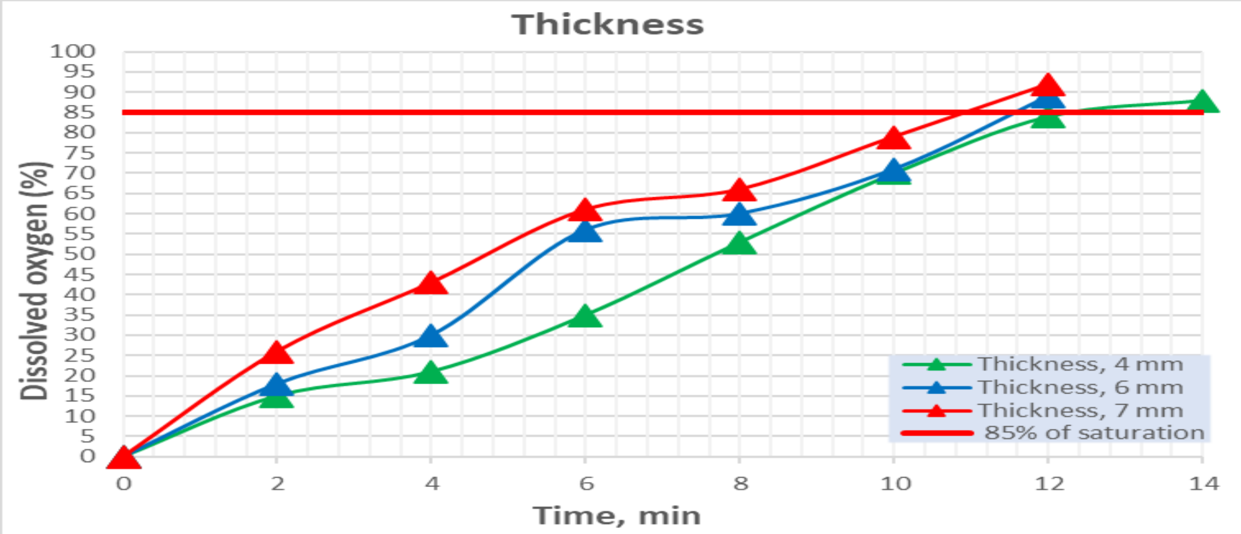



Fig. 6. Impact of diffusion tube wall width on saturation time for 0.554 $m^3.h^{-1}$ air flow quantity and circular form design and 0.3 m depth
Source: Authors' determination.

This might be described as an increase in air flow rate generated an rise in bubble size, which in turn instigated an rise in bubble velocity, resulting in less time spent in water and less overlap between air and water.

***b) The effect of depth from water surface on saturation time***

The increase of depth from water surface from 0.3 to 0.7 m resulted in decrease at saturation time with 15 % (from 13 to 11.5 minutes) at air flow rate from 0.556 $m^3.h^{-1}$, tube wall thickness of 4 mm and circular design shape as shown in figures 4, 5 and 6.

Increased interaction time between water and diffused air resulted in an increase in saturation time when depth from the water surface was increased.

***c) The effect of tube wall thickness on saturation time***

The increase of tube wall thickness from 4 to 7 mm resulted in decrease at saturation time with 15.3 % (from 13 to 10.5 minutes) at air flow rate from 0.556 $m^3.h^{-1}$, depth from water surface of 0.3 m and circular design shape as shown in figures 4, 5 and 6.

This could be because increasing the thickness resulted in a drop in pore widths, resulting in a reduction in the size of generated bubbles with a low velocity and longer interaction time.

**d) The effect of shape design on saturation time**

The changing of shape design from circular to longitudinal led to increase in saturation time with 3.8 % (from 13 to 13.5 minutes) at air flow rate from 0.556 $m^3.h^{-1}$, depth from water surface of 0.3 m and tube wall thickness of 4 mm as shown in Figures 4, 5 and 6.

When the shape was changed from circular to longitudinal, the projected area dispersed.

**Effect of aeration by fine bubbles on oxygen mass transfer coefficient**

Figures 7, 8 and 9 show the impact of air flow rate, deepness from the surface, thickness of tube wall and design form on the oxygen mass transfer coefficient.

The highest measure of oxygen mass transfer coefficient was 11.581 $h^{-1}$ under operational parameters of 0.554 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from water surface, 7 mm for tube wall thickness and circular design shape as shown in Figures 7, 8 and 9.

The minimum value of oxygen mass transfer coefficient was 3.899 $h^{-1}$ below operational conditions of 1.246 $m^3.h^{-1}$ for aeration flow rate, 0.30 m for deepness from water surface, 4 mm for tube wall thickness and longitudinal design form.

***a) The impact of aeration flow rate on the oxygen mass transfer coefficient***

The rise of air flow quantity from 0.554 to 1.246 $m^3.h^{-1}$ caused to lower oxygen mass transfer coefficient with 17.38 % (from 5.425 to 4.482 $h^{-1}$) at depth from water surface of 0.30 m, tube wall thickness of 4 mm and

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circular design shape as shown in Figures 7, 8 and 9.

This result could be explained as increase in air flow rate led to increase in bubble size which caused increase in bubble velocity so, the time spent in water and overlap between air and water reduced. So, the relationship between oxygen mass transfer factor and air flow quantity was inverse relationship.

***b) The impact of depth from water surface on the oxygen mass transfer coefficient***

The increase of submergence from water surface from 0.3 to 0.7 m caused in rise at oxygen mass transfer coefficient with 53.53 % (from 5.425 to 8.329 $h^{-1}$) at air flow rate from 0.554 $m^3.h^{-1}$, tube wall thickness of 4 mm and circular design shape as shown in Figures 7, 8 and 9.

Increasing depth from water surface led to increase interaction time between water and diffused air so increase in oxygen mass transfer coefficient.

***c) The impact of tube wall thickness on the oxygen mass transfer coefficient***

The growing of tube wall thickness from 4 to 7 mm caused in rise at oxygen mass transfer coefficient with 37.82 % (from 5.425 to 7.477 $h^{-1}$) at air flow rate from 0.554 $m^3.h^{-1}$, depth from water surface of 0.3 m and circular design shape as shown in figures 7, 8 and 9.

This result may be due to increasing the thickness which led to decrease in pores diameters consequently decrease at size of produced bubbles which had low velocity and more interaction time.

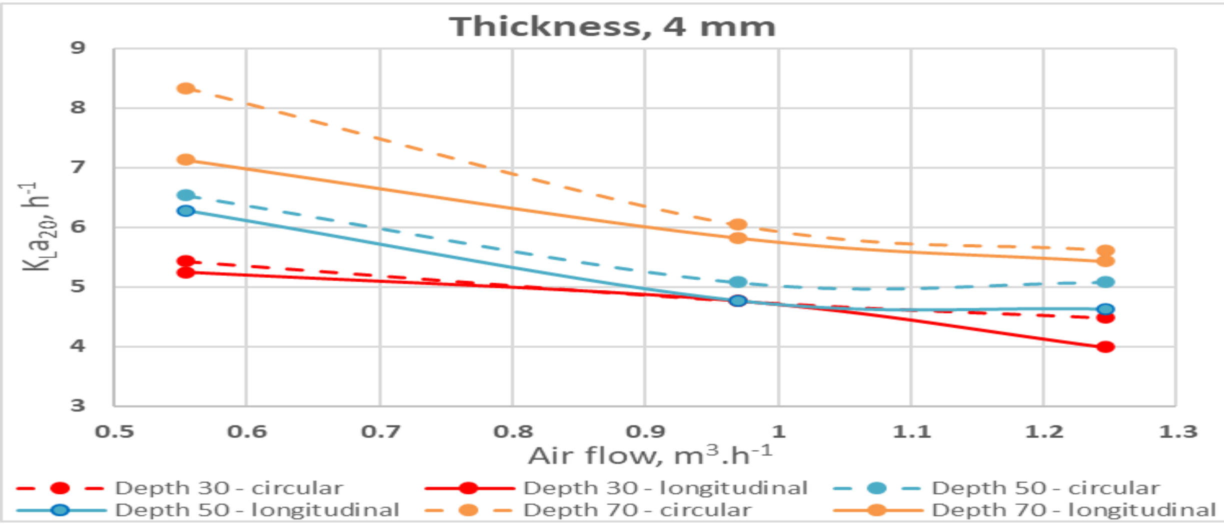


Fig. 7. Effect of air flow rate, depth and shape design on the oxygen mass transfer coefficient for 4 mm wall thickness
Source: Authors' determination.

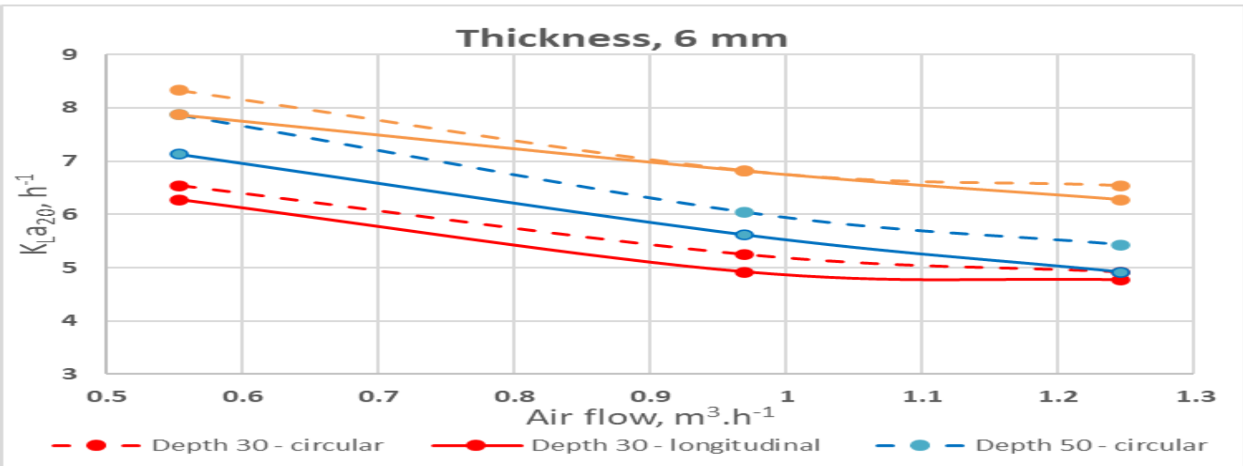


Fig. 8. impact of air flow quantity, submergence and form design on the oxygen mass transfer coefficient for 6 mm wall thickness
Source: Authors' determination.

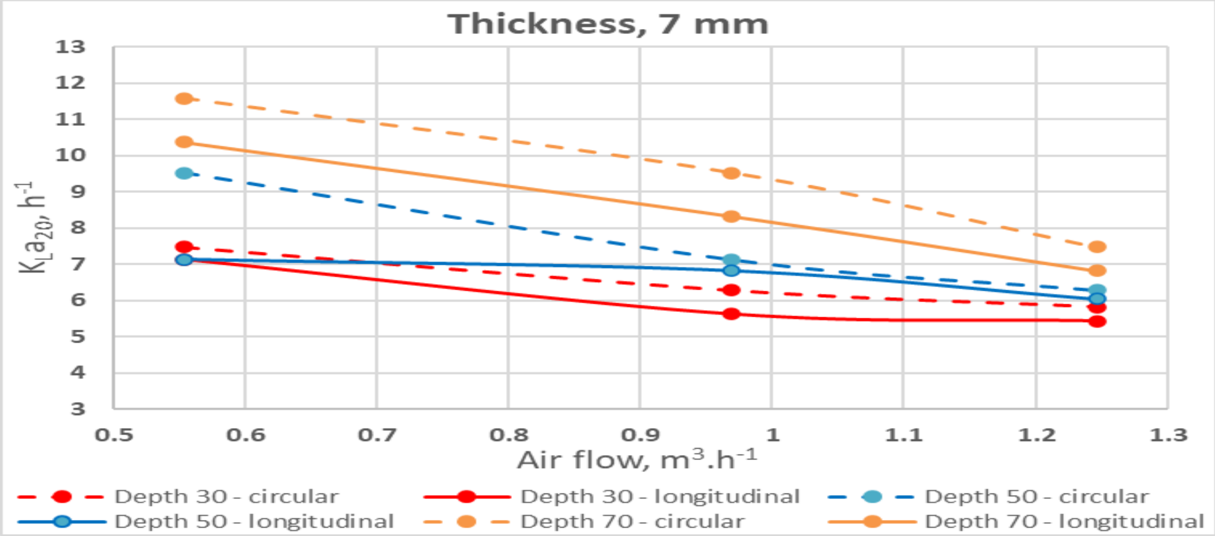


Fig. 9. impact of air flow quantity, submergence and form design on the oxygen mass transfer coefficient for 7 mm wall thickness
Source: Authors' determination.

***d) The impact of form design on the oxygen mass transfer coefficient***

The varying of form design from circular to longitudinal caused decrease of oxygen mass transfer coefficient with 3.3 % (from 5.425 to 5.246 $h^{-1}$) at air flow rate from 0.554 $m^3.h^{-1}$, depth from water surface of 0.3 m and tube wall thickness of 4 mm as shown in figures 7, 8 and 9. Changing shape design from circular to longitudinal led to dispersal in projected area.

**Effect of aeration by fine bubbles tubes on standard aeration efficiency**

Figure and table show the influence of air flow rate, depth from the surface, thickness of tube wall and design shape on standard aeration efficiency.

The maximum value of standard aeration efficiency was 2.66 kg.$O_2$/kW.h under operational parameters of 0.556 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from water surface, 7 mm for tube wall thickness and circular design shape as shown in Figures 10, 11 and 12.

The minimum value of standard aeration efficiency was kg.$O_2$/kW.h under operational parameters of 0.1.246 $m^3.h^{-1}$ for air flow rate, 0.30 m for depth from water surface, 4 mm for tube wall thickness and longitudinal design shape.

***a) The impact of air flow rate on standard aeration efficiency***

The rise of air flow rate from 0.554 to 0.1.246 $m^3.h^{-1}$ leaded to decrease at standard aeration efficiency with 67 % (from 1.246 to 0.411 kg.$O_2$/kW.h) at depth from water surface of 30 mm, tube wall thickness of 4 mm and circular design shape as shown in Figures 10, 11 and 12.

This result could be explained as increase in air flow rate led to increase in bubble size which caused increase in bubble velocity so, the time spent in water and overlap between air and water decreased. Hence the association between Standard aeration efficiency and aeration flow rate was inverse relationship.

***b) The impact of submergence from water surface on standard aeration efficiency***

The increase of depth from water surface from 0.3 to 0.7 m resulted in increase at standard aeration efficiency with 53.5 % (from 1.246 to 1.913 kg.$O_2$/kW.h) at air flow rate from 0.556 $m^3.h^{-1}$, tube wall thickness of 4 mm and circular design shape as shown in Figures 10, 11 and 12.

Increasing depth from water surface led to increase interaction time between water and diffused air so increase in Standard aeration efficiency.

***c) The effect of tube wall thickness on standard aeration efficiency***

The increase of tube wall thickness from 4 to 7 mm resulted in increase at standard aeration efficiency with 37.8 % (from 1.246 to 1.717 kg.$O_2$/kW.h) at air flow rate from 0.556 $m^3.h^{-1}$,

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depth from water surface of 0.3 m and circular design shape as shown in figures 10, 11 and 12.

This result may be due to increasing the thickness which led to decrease in pores diameters consequently decrease at size of produced bubbles which had low velocity and more interaction time.

***d) The effect of shape design on standard aeration efficiency***

The changing of shape design from circular to longitudinal led to decrease of standard aeration efficiency with 3.4% (from 1.246 to 1.204 kg.$O_2$/kW.h) at air flow rate from 0.556 $m^3.h^{-1}$, depth from water surface of 0.3 m and tube wall thickness of 4 mm as shown in Figures 10, 11 and 12.

Changing shape design from circular to longitudinal led to dispersal in projected area.

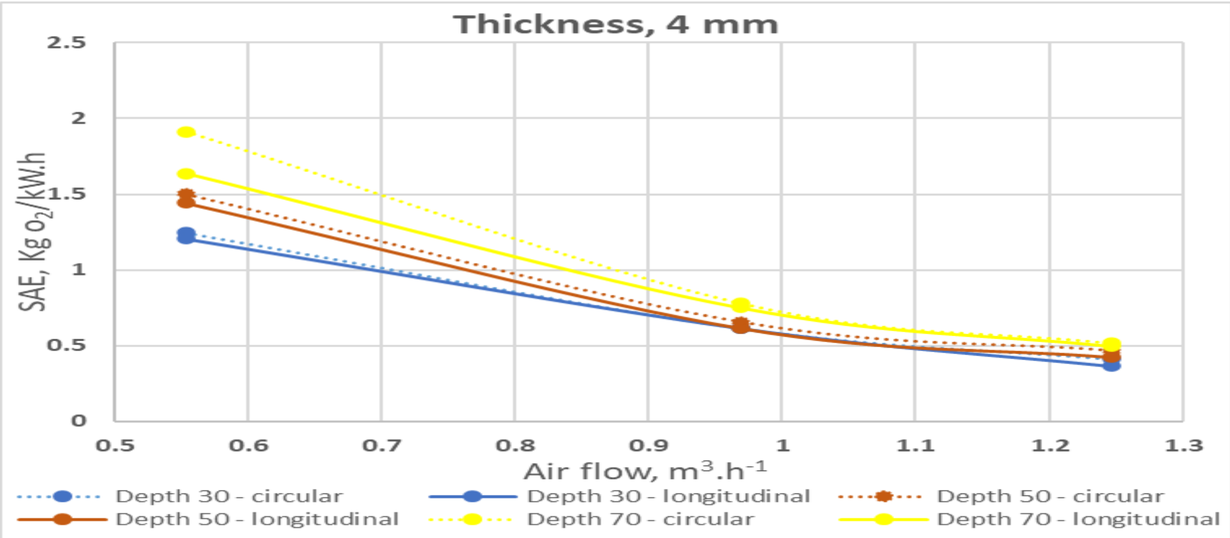


Fig. 10. Impact of air flow rate, submergence and form design on standard aeration efficiency for 4 mm wall thickness. Source: Authors' determination.

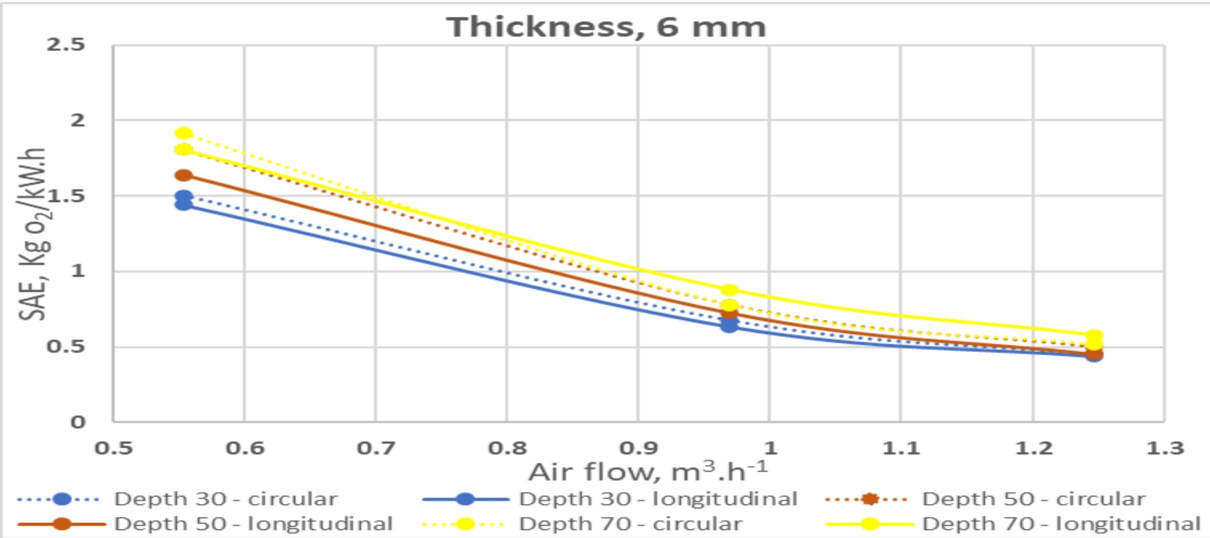


Fig. 11. Impact of aeration flow rate, submergence and form design on standard aeration efficiency for 6 mm wall thickness. Source: Authors' determination.

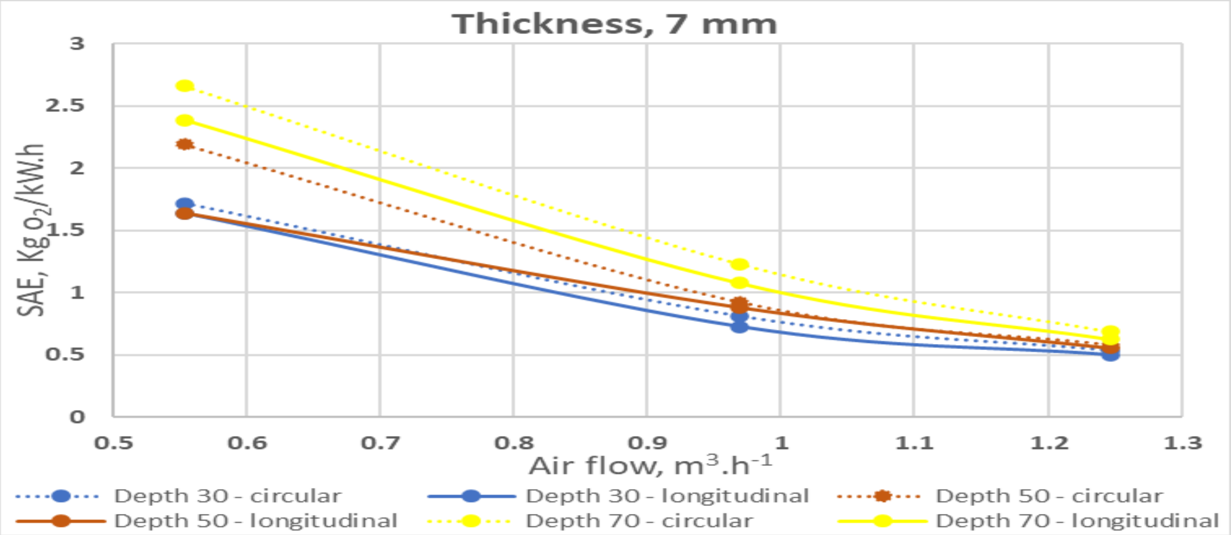


Fig. 12. Impact of aeration flow rate, submergence and form design on standard aeration efficiency for 7 mm wall thickness. Source: Authors' determination.

## CONCLUSIONS

The experimental research found that:

-The relationship between oxygen mass transfer coefficient and operational parameters were as flow: inverse relationship with air flow rate, inverse relationship with depth from water surface, positive relationship with tube wall thickness and increases with circular shape design more than longitudinal.

-The relationship between standard aeration efficiency and operational parameters were as flow: inverse relationship with air flow rate, inverse

-Relationship with depth from water surface, positive relationship with tube wall thickness and increases with circular shape design more than longitudinal.

-As mentioned above the relationship between saturation time and operational parameters were as flow: positive relationship with air flow rate, positive relationship with depth from water surface, inverse relationship with tube wall thickness and increases with longitudinal shape design more than circular.

- The maximum value of standard aeration efficiency was 2.66 kg.$O_2$/kW.h under operational parameters of 0.554 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from the water surface, 7 mm for tube wall thickness and circular design shape.

- The minimum value of saturation time was 8 minutes under operational parameters of 0.554 $m^3.h^{-1}$ for air flow rate, 0.70 m for depth from the water surface, 7 mm for tube wall thickness and circular design shape.

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# MANUFACTURING AND TESTING OF LOCAL RICE TRANSPLANTING MACHINE

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**Abstract**

*Mechanical transplanting of rice is considered one of the safest methods of rice cultivation. It is also one of the most desirable methods for Egyptian farmers, saving about 70% of the seeds, saving labor costs, better plant density, water saving, and weed control. Due to the fragmentation of agricultural holdings in Egypt and the high costs of mechanical transplanting with imported machines, the research aimed to manufacture a rice transplanting machine with local materials suitable for small rice holdings and achieve the technical recommendations of Egyptian conditions. Also, testing and evaluating the manufactured machine under different operation conditions. The rice transplanting machine was manufactured and tested at the Rice Mechanization Center, Agricultural Engineering Research Institute, Egypt. The machinecontains five rows and the distance between each row is 20 cm. The manufactured transplanter was tested and evaluated under four different forward speeds (1.00, 1.25, 1.50, and 1.75 km/h), four different intra-row hill spacing (16, 18, 20, and 22 cm), and two seedling cross-section area (1.00 and 2.00 cm$^2$). The obtained results indicated that the lowest percentages of missing, floating, and damaged hills were 2.92, 1.83, and 0.27%, respectively.The highest transplanting efficiency and field efficiency were94.98 and 83.75%, respectively, obtained at themachine forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm$^2$. Also, the lowest value of requirement energy was 4.599 kW.h/fed, which achieved the highest actual field capacity of 0.285 fed/h obtained at forward speed of 1.75 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 1.00 cm$^2$.*

***Key words***: *mechanical transplanting, local rice transplanter, hill spacing, rice seedlings*

## INTRODUCTION

Rice (*Oryzasativa* L.) is the most popular grain crop in Egypt because it is considered the major food for over 50% of Egyptians. Egypt cultivated about 1.309 million feddan of rice with a total production of about 4.89 million tons [5]. Mechanization of the operations in rice crop in Egypt is very important from seeding till harvesting [6]. The direct seeding of rice and transplanting are the two common rice cultivation methods. The transplanting method is more prevalent among farmers because of less weed growth and higher yield than direct seeded rice [9]. Rice is largely grown traditionally by manual transplanting. Manual transplanting requires numerous labors besides involving drudgery, and is also expensive. The scarcity of labor is another main problem in some paddy-growing areas in our country [1]. The mechanical transplanting of paddy has been considered the most promising option, as it saves labor, ensures timely transplanting, and attains optimum plant density that contributes to high productivity [10]. The mechanical transplanting offers higher field capacity than manual transplanting. Thus, farmers can transplant rice seedlings within an appropriate and very short time by mechanical transplanter [7]. Abdrabo [2] developed a double-purpose machine prototype for rice transplanting, locally manufactured, and evaluated. The proposed transplanter is 4 rows planting machine, and propelled on three ground wheels to suit small-scale farms. It fits both the traditional rice seedlings method, and the trays seedling method. The obtained results revealed that the maximum field capacity values were 0.29, and 0.283 fed/h, and the highest transplanting efficiency values were 72 and 68%, as the developed prototype was accomplishing the traditional, and in trays seedling methods. The present rice transplanters rows spacing is fixed at 30 cm, and this distance does not agree with technical recommendations for rice cultivation in Egypt. So he modified the planting unit mechanisms of a Japanese rice transplanter to suit narrow row spacing (20 cm). The developed transplanter was tested under different operating speeds (6.98, 7.85, and 8.96 m/s) to get different spaces under actual field conditions. He found that the lowest defective hills percentage was 4.3% and the highest distribution uniformity of lateral space was 99% was achieved as the developed machine at a finger speed of 6.98 m/s compared to 3.9% and 99.5% for the transplanter before modifications [4].Asha et al. [3] developed a manual (pull-type) two-row paddy transplanter. The developed transplanter can be helpful for small and marginal landholdings. They develop equipment that should be low-cost, fabricated locally, versatile in utility, reducing drudgery by making transplanting possible without bending, and useful for small farmers. The actual field capacity of 0.2 ha/day (8hours working daily) was achieved with the machine by considering a 5% - and 3%-time loss because of turning and filling trays, respectively. RRTC [11] recommended that planting spaceis 20 × 15 or 20 × 20 cm(row spacing × hill spacing)for Egyptian rice variety Sakha super 300 to obtain the higher grain yield The problems of this research are that the rice transplanters are imported from abroad at a high price, especially for smallholdings. Also, the distance between the rows of the transplanter is 30 cm, and this distance does not meet the farmer's desire in terms of the required density. Also, it does not fulfill the recommendations of the Rice Research Department, which recommends that the distance between the rows must be 20 cm to achieve the required plant density under Egyptian conditions. Therefore, the objectives of the current study areto manufacture a rice transplanting machine with local materials suitable for small rice holdings,and achieve the technical recommendations of Egyptian conditions. Also, testing and evaluating the manufacture machine under different operation conditions.

## MATERIALS AND METHODS

The field trials were executedatRice Mechanization Center, Meet El Deeba, Kafr-El-Sheikh Governorate, Egypt, during the agricultural season of 2022 for Sakha super 300 (common Egyptian rice variety)

**Materials**

**The manufactured ricetransplanting machine**

The manufactured rice transplanting machine consists of main frame, transplanting unit, power source, power transmission system, guide rail, seedlings mat, floats, and drive wheels. The machine contains five rows, and the distance between each row is 20 cm,as shown in Photo 1.

Photo 1. The manufactured rice transplanting machine
Source: Authors' own illustration.

### 1. Main frame

The main frame of the manufactured transplanterwas made from square mild steel hollow sections (20×20×1.25 mm, height, width, and thickness, respectively).The main frame dimensionswere1300×950×440 mm, length, width, and height, respectively. The square sections were cut and welded together to form the main frame, as shown in Photo 2.

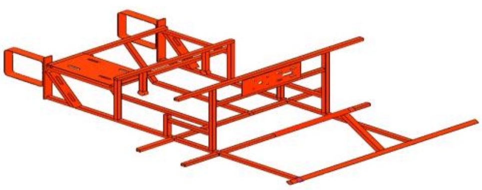

Photo 2. The main frame of the manufactured rice transplanting machine
Source: Authors' drawing.

## 2. Transplanting unit

The function of the transplanting unit is to pick the selected number of seedlings from the seedlings mat and transplant it into the soilin a standing position. It consists of two mechanisms. The first one is the transplanting mechanism which includes a transplanting arm (four-bar linkage mechanism), a finger holder with five planting tines, and a crankshaft to operate the mechanism. The second mechanism is the seedling push mechanism, which includes five seedling push rods mounted on one shaft called the push rods holder, two cams equipped with two levers, and four springs.

### A. Four-bar linkage mechanism

A four-bar linkage is the simplest movable closed chain linkage. It consists of four bars or links connected together by four joints, as shown in Fig. 1. The lengths of the linkages vary from one another. One of the rotating links is known as the crank or driver, and the other link is a rocker. The member connecting the crank and the rocker is known as a coupler, and a fixed link is the frame. The crank is the shortest link and makes a complete revolution. The lengths of links were 50, 150, 100, 150, and 200 mm for the crank, fixed link, rocker, coupler, and coupler extension, respectively.

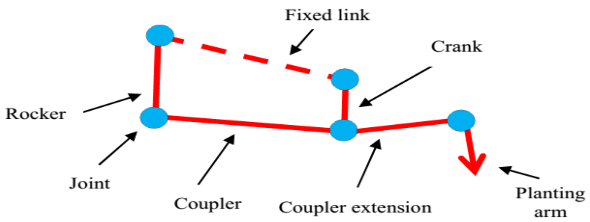


Fig. 1. Four-bar links mechanism
Source: Authors' own illustration.

### B. Planting tines and tines holder

The planting tines are the main element thatis responsible for the plantation of the seedlings. It has aspecific shape thatpicks the seedlings and plantsthemin the mud. The tines holder is a horizontal bar of rectangular mild steel hollow sectionswith dimensions of 20 × 40 ×1,000 mm width, height, and length, respectively, and welded on it five pieces of square mild steel hollow sections with dimensions of 15 × 15 ×100 mm width, height, and length, respectively.Every piece of this square mild steel hollow sections installed on it two bolts with nuts to control the adjustment of the planting tines with pushing rods. The tines holder is mounted on the transplanting arm (four-bar linkage) via a hinged joint to control the height of the seedlings cut from the mat and thus control the vertical feeding of the machine. The machine contains five planting tines, and the distance between every planting tine is 20 cm, as shown in Photo 3.

### C. Seedling push mechanism

**Seedlings push rods**

The push rods are the member responsible for pushing seedlings into the soil. It is a steel rod with a diameter of 8 mm and a length of 250mm. Itwelded at the end of the rod a piece of steel in the form of U- shape, and this piece slides inside the planting tines up and down to push the seedlings into the soil. It is fixed from the top by nuts in a horizontal bar called the push rod holder and fixed from the bottom inside a piece of square mild steel hollow sections with dimensions of 15 × 15 ×100 mm width, height, and length, respectively, to determine its path inside the planting tines.

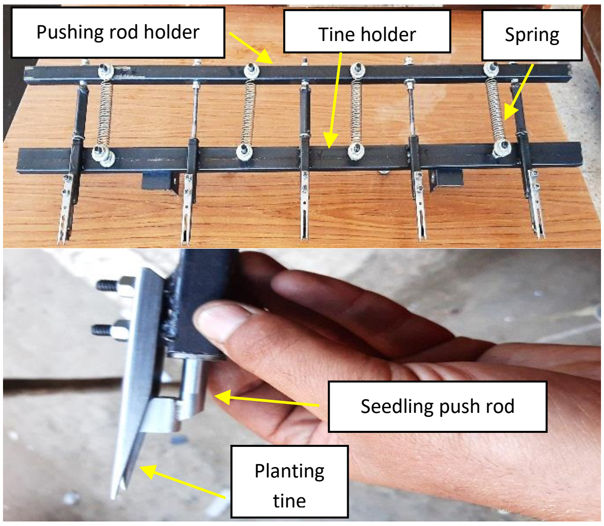


Photo 3. Seedlings push holder and seedlings pushrod
Source: Authors' own illustration.

The pushing rod holder is a horizontal bar of square mild steel hollow sections,with dimensions of 20 × 20 ×1,000 mm width, height, and length, respectively. The push rod holder is connected with the planting tines holder by four tension springs to push the seedlings pushing rod holder with the push rods inside the planting tines for pushing the seedlings into the soil, as shown in Photo 3.

**Cams and levers**

The machine contains two circular cams with a diameter of 100mm and a thickness of 10mm. A quarter of a circle cam was cut from each cam, and then they were fixed from the middle on the crankshaft extension. The machine also contains a pair of steel iron levers rolled into a Z-shape. The length of the lever from the top was 80 mm and from the bottom 100 mm, and the lever height was 160 mm; each lever is fixed by a nail installed on the transplanting arm so that part of it is located below the pushing rod holder and the other part is below the cams, as shown in Photo 4.The function of the cams and levers is to control the movement of the pushing rod holder, whether by lifting or pushing.

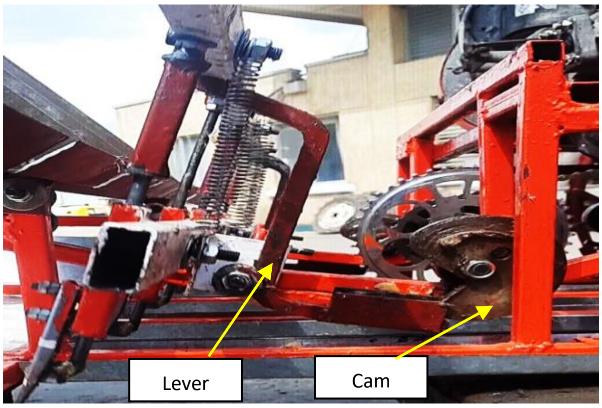


Photo 4. Cams and levers
Source: Authors' own illustration.

## 3. Power source

The power source of the rice transplanting machine is a 3kW engine, model GS130-2CN from Kubota. The engine power was transmitted to an internal attached gear box that reduced engine rotation speed between 60-100 rpm on the output shaft. The clutch was also provided to connect and disconnect power from the engine.

## 4. Power transmission system

The power transmission system contains three parts; the main engine shaft, the intermediate reduction unit, and the drive wheel's unit, as shown in Photo 5. The main shaft contains four different sprockets with 20, 25, 30, and 35 teeth to change the machine's forward speed in the field. The intermediate reductionunit is a round shaft with a diameter of 25 mm and 600 mm length. The shaft is installed inside two bearingsthat have the same diameter. The intermediate reduction unit was installed on itthree different sprockets with 49, 48, and 15 teeth. The drive wheel unit is a round shaft with a diameter of 25 mm and 1,200 mm length used as a wheel axle; itis installed inside two bearingswith the same diameter and installed on it a sprocket with 49 teeth.The movement was transmitted from the main engineshaft with different sprockets to the intermediate reduction unit sprockets by chains. The main shaft sprockets were connected to the 49-teeth sprocket in the intermediate reduction unit by a chain to reduce the output rotational speed of the engine. The intermediate reduction unit deliversmotion power from the engine and transmits it to the transplanting unit (A) and the drive wheel(B).

### A. Transmit motion to transplanting unit

The movement is transmitted to the transplanting unit by sprockets and chains that are mounted on the intermediate reduction unit and transplanting unit axle. The movement is transmitted by a sprocket of 48 teeth installed on the intermediate reduction unit and connected to the transplanting unit axle by another cassette sprocket withsevensprockets (speeds) starting from 14 to 28 teeth. Its purpose is to change the number of hits of the transplanting unit per unit distance to obtain different intra-row hill spacing.

### B. Transmit motion to drive wheel

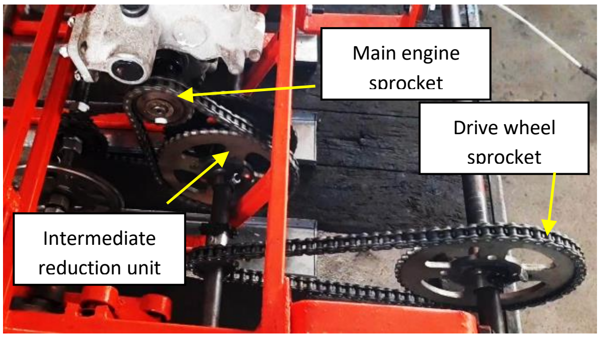


Photo 5. Power transmission system
Source: Authors' own illustration.

The movement is transmitted to the traction wheel by the 15-teeth sprocket installed on the intermediate reduction unit, and the 49-teeth sprocket installed on the axle of the drive wheel to reduce the machine's forward speed in the field to be proportional tothe desired hills spacing. The intermediate sprockets are connected to the wheel drive sprocket by a chain.

**5. Guide rail**

The guide rail is a L-shape steel section has dimensions of 40 × 40 × 1,300 mm, height, width and length, respectively with a thickness of 2.5 mm welded with a rectangular mild steel hollow section has dimensions of 20 × 40 × 1,300 mm, height, width and length, respectively with a thickness of 1.25 mm and fixed to the machine frame by adjustable screws. The guide rail has five slots through which seedlings are picked by planting tines.The width of the slot is 18 mm, the length is 65 mm, and the distance between the slot and the other is 188 mm. Slots were cut by a CNC machine to ensure cuttingaccuracy. The guide rail performs several functions, picking up the seedlings through it, and the seedling mat slides on it horizontally with a distance of 188 mm back and forth, as shown in Photo 6.

**6. Seedlings mat**

The seedlings mat was manufacturedwith a galvanized steel sheet with dimensions of 1,030×700 mm,width and length,respectively, with a thickness of 0.7 mm. It was divided into five compartments; the width of each compartment is 196 mm, and the separator between each compartment was made of square mild steel hollow sections with a dimension of 15×15×740 mm.

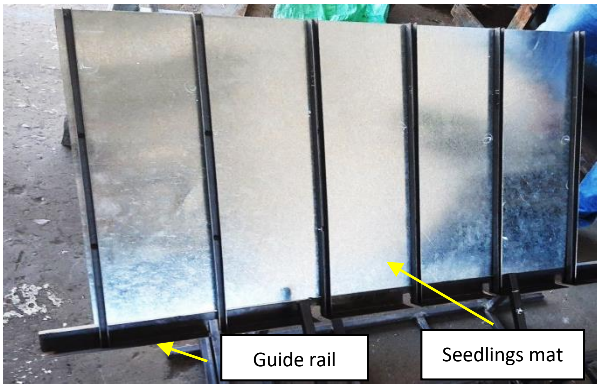


Photo 6. Seedling mat and guide rail
Source: Authors' own illustration.

The seedlings mat rests on the guide rail from the down side and the machine chassis from the upper side. It was fitted at a 50° angle and supported from the rear side by a 20×20 mm square mild steel hollow sections frame.After every stroke of the transplanting arm, the seedlings mat slides horizontally along with a guide rail with a distance of 188 mm back and forth bythe mat movement mechanism, as shown in Photo 7.

**7. Floats**

The floats were made of a galvanized steel sheet and consist of two parts.The first one is the main float, and this part is one piece installed in front of the transplanter with bolts and has a dimension of 1,000×600 width and length, respectively, with a thickness of 0.7 mm. The floats were curved with a height of 150 mm from two sides and front to avoid the entry of soil on it, and this float work as a leveler and puddler. The second part is the secondary floats,consisting of four small floats installed in the rear section of the transplanter and fixed between rows of seedlings. Each one of the floats has a dimension of 80×700mm width and length, respectively, with a thickness of 0.7 mm, and the floats were curved with a height of 40 mm from two sides. The cross-section of the floats was made such that the soil in between the two floats will project up,ensuringgood placement of the seedling into it, as shown in Photo 7.

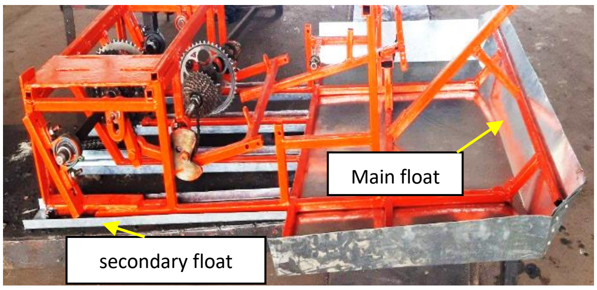


Photo 7. Rice transplanter floats
Source: Authors' own illustration.

**8. Drive wheels**

Two drive wheels of rubber lug wheel with thick rim were used in the transplanter. The wheel diameter was 600 mm. The wheels were installed on an axle shaft with 25 mm diameter and 1,200 mm length; this shaft was installed between two bearings, and the distance between wheels on the shaft was

1,000 mm to avoid damaging the seedlings on the way to go and back.

**Soil conditions before transplanting**

In order to obtain satisfactory operation, good quality work, and efficiency of the developed machine, besides ensuring good technical condition and correct operation of the machine, suitable soil conditions in the field should be available. Soil conditions before transplanting were shown in Table 1.

Table 1.Field condition before transplanting

| Item | Treatment |
|---|---|
| Water depth, cm | 1 - 2 |
| Hardpan depth, cm | 13 |
| Hardpan hardness (kg/cm$^2$) | 5.4 |
| Cone depth, cm | 8 |
| Soil penetration resistance, kg$_f$/cm$^2$ | 24 |
| Soil texture | Clay |

Source: Authors' determination.

**Plant parameter**

Before starting the operation, the data on the targeted crop were collected, which was required for the proper functioning of the transplanter.

Table 2.Mean values of some seedlings characteristics of rice crop variety (Sakha super 300)

| Characteristics | Mean values |
|---|---|
| Crop variety | Sakha super 300 |
| Recommended transplanting distance (cm) | 20 × 20 |
| Age of seedling (days) | 25 |
| Seedlings height (cm) | 17 |
| Number of leaves | 2.5-3.0 |
| Number of plant / cm$^2$ | 4 |

Source: Authors' determination.

Photo 8. Rice transplanter in the experimental field
Source: Authors' own illustration.

The selected variety was (Sakha super 300) and recommended spacing was 20×20 cm [11]. After treatment, sprouted rice seed was sown in trays at a 250 g/tray seed rate. Seedling conditions recorded on the day of the transplanting operation are shown in Table 2.

**Methods**

**1.Studied factors:** The experiments were carried out to study some factors affecting on the performance of rice transplanting machine, such as:

(a)**Machine forward speed:** four different forward speeds, i.e., 1, 1.25, 1.5, and 1.75 km/h

(b)**Intra-row hill spacing:** fourdifferent intra-row hill spacing, i.e., 16, 18, 20, 22 cm

(c)**Seedling cross-section area:** twodifferent seedling areas,i.e., 1.00 and 2.00 cm$^2$

All tests were carried out at a constant seedlings depth of 5 cm.

**2.Measuring indicators**

**Percentage of missing seedlings ($P_m$)**

The percentage of missing seedlings was calculated according to RNAM [12], as follows in Eq. (1):

$$P_m = (N1/N2) \times 100, \quad (1)$$

where:

$P_m$= Percentage of missed seedlings (%)
N1 = Missing seedlings number per unit area
N2 = The theoretical number of seedlings per unit area

**Percentage of floating seedlings ($P_f$)**

The percentage of floating seedlings was calculated according to RNAM[12], as follows in Eq. (2):

$$P_f = (N3/N2) \times 100, \quad (2)$$

where:

$P_f$ = percentage of floating seedlings (%)
N3 = Floating seedlings number per unit area
N2 = The theoretical number of seedlings per unit area

**Percentage of damaged seedlings ($P_d$)**

The percentage of damaged seedlings was calculated according to RNAM[12], as follows in Eq. (3):

$$P_d = (N4/N2) \times 100, \quad (3)$$

where:

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$P_d$ = percentage of damaged seedlings (%)
N4 = Damaged seedlings Number per unit area
N2 = The theoretical number of seedlings per unit area

**Transplanting efficiency**

Transplanting efficiency for each treatment was determined according to Eq. (4):

$$TE = [N_t - (N_d + N_m + N_f)] / N_t, \%............(4)$$

where:
TE = Transplanting efficiency (%)
$N_t$= Theoretical number of seedlings per unit area
$N_d$ = Number of damaged seedlings per unit area
$N_m$= Number of missed seedlings per unit area
$N_f$= Number of floated seedlings per unit area

**Actual field capacity**

The actual field capacity was calculatedaccording toKepner et al. [8], as follows in Eq. (5):

$$Af_c= 1/T \;...................................\; (5)$$

where:
$Af_c$ = Actualfield capacity, fed/h
T = The total transplanting time
$T = t_1 + t_2 + t_3$
$t_1$ = Actual time of operation (straight time)
$t_2$ = Timelost for turning
$t_3$ = Time lost for repairing and adjusting the machine

**Energy requirements (kW.h/fed)**

The energy requirements were calculated by dividing engine power on actualfield capacity, as follows in Eq. (6):

$$\text{Energy requirements} = \frac{\text{Engine power (kW)}}{\text{Actual field capacity}}, \text{(kW.h/fed)}........ \textbf{(6)}$$

## RESULTS AND DISCUSSIONS

The data obtained from the present studycould be summarized under the following headings.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on missing hills percentage**

The relationship between the missing hills percentage and the machines' forward speeds at different intra-row hill spacingandseedling cross-section area is shown in Fig. 2.

The data shows that increasing the forward speed tends to increase the missing hills percentage; which may be attributed to the increase in the rotational speed of the transplanting arm.

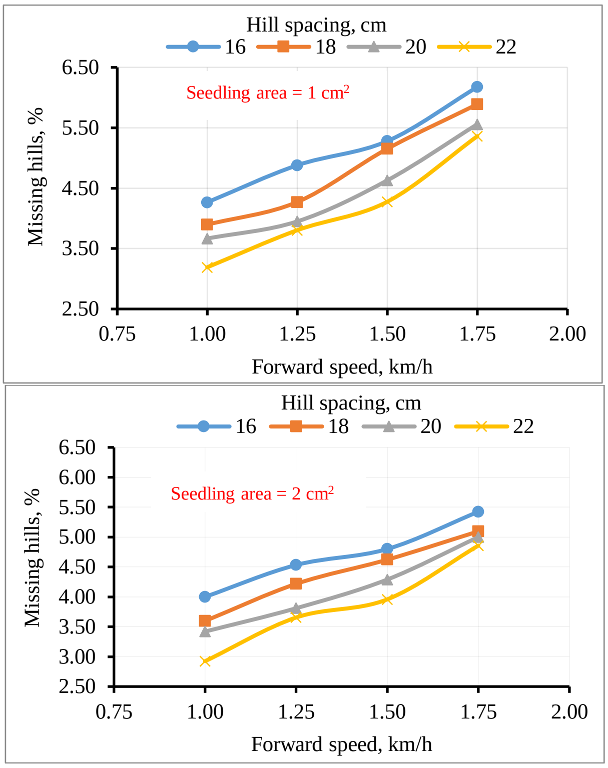


Fig. 2. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on missing hills percentage
Source: Authors' determination.

Where a sincreasing intra-row hill spacing and seedling cross-section area decreased the missing hill percentage, this is may be attributed to the decrease in the rotational speed of the transplanting arm and the increase in the seedling cross-section area led to an increase in the finger pick-up efficiency.In the case of the seedling cross-section area of 1.00 cm$^2$, the results revealed thatincreasing the forward speed from 1.00 to 1.75 km/h increased the missing hills percentage from 3.19-5.36, 3.67-5.56, 3.90-5.89 and 4.37-6.18% at intra-row hill spacing of 22, 20, 18 and 16 cm, respectively.On the other side, at a seedling cross-section area of 2.00 cm$^2$, the results indicated that increasing the intra-row hill spacing from 16 to 22 cm decreased the missing hills percentage from

5.42-4.86, 4.80-3.96, 4.53-3.65 and 4.00-2.92% at a forward speed of1.75, 1.50, 1.25 and 1.00 km/h, respectively.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on floating hills percentage**

Figure 3 shows that increasing the forward speed tends to increase the floating hills percentage; this may be attributed to the increase in the rotational speed of the transplanting arm.

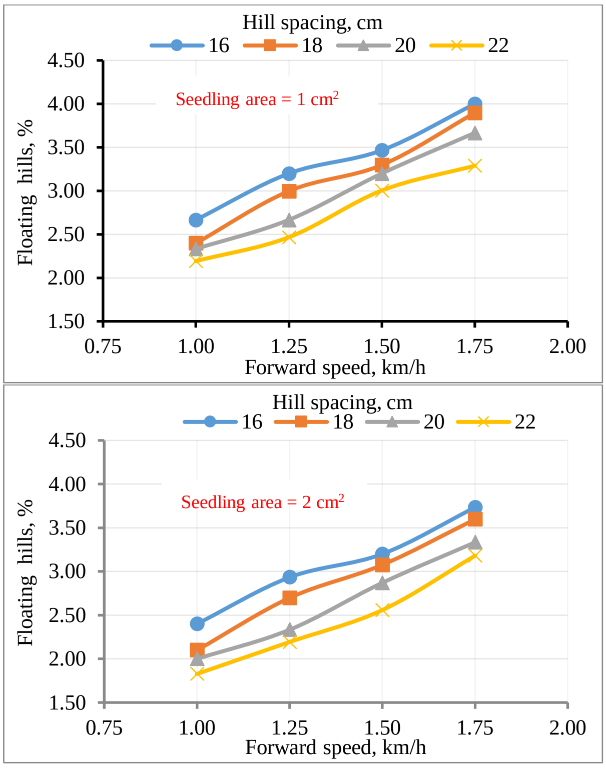


Fig. 3. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on floating hills percentage
Source: Authors' determination.

Whereas increasing intra-row hill spacing and seedling cross-section area tends to decrease the floating hill percentage, this may be attributed to the decrease in the rotational speed of the transplanting arm and the increase in the seedling cross-section area led to increase the transplanting efficiency. The results indicated that the lowest missing hills percentage was 1.83%, obtained at a forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm$^2$. On the other hand, the highest floating hills percentage was 4.00%, obtained at a forward speed of 1.75 km/h, intra-row hill spacing of 16 cm, and seedling cross-section area of 1.00 cm$^2$.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on damaged hills percentage**

The presented data in Fig. 4 illustrates the relationship betweenthe damaged hills percentage and the machines' forward speeds at different intra-row hill spacing and seedling cross-section area.

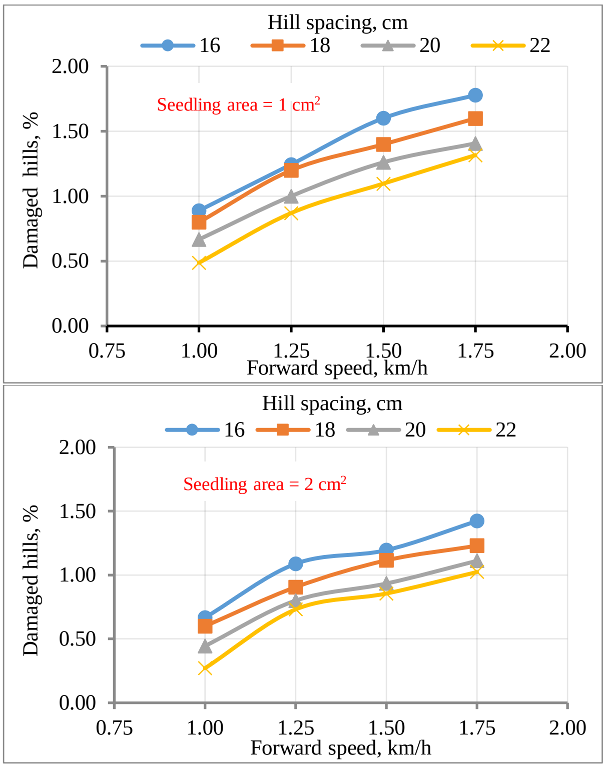


Fig. 4. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on damaged hills percentage
Source: Authors' determination.

The same trend was observed in the damaged hills percentage, as stated in the missing and floating hills percentage.The results showed that the lowest damaged hills percentage was 0.27%, obtained at a forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 cm$^2$. Whereas, the highest damaged hills percentage was 1.78%, obtained at a forward speed of 1.75 km/h, intra-row hill spacing of 16 cm, and seedling cross-section area of 1.00 cm$^2$.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on transplanting efficiency**

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The relationship between the transplanting efficiency and the machines' forward speeds at different intra-row hill spacingandseedling cross-section area is shown in Fig. 5. The data shows that increasing the forward speed tends to decrease the transplanting efficiency; whichmay be attributed to the increase in the transplanting losses.

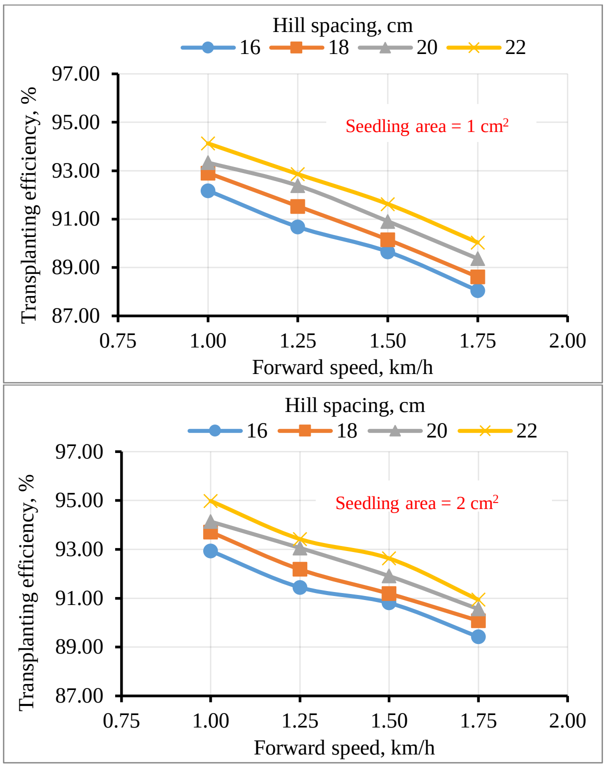


Fig. 5. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on transplanting efficiency
Source: Authors' determination.

While an increase in intra-row hill spacing and seedling cross-section area tend to increase the transplanting efficiency. It was observed that, in the case of the seedling cross-section area of 1.00 $cm^2$, the transplanting efficiency recorded 94.13% and 92.18% witha forward speed of 1.00 km/h and decreased to 90.03% and 88.05% at a forward speed of 1.75 km/h when the intra-row hill spacing was 22 and 16 cm, respectively. Whereas, at seedling cross-section area of 2.00 $cm^2$, the results showed that increasing the intra-row hill spacing from 16 to 22 cm increased the transplanting efficiency from 89.42-90.94, 90.81-92.63, 91.45-93.42 and 92.93-94.98% at a forward speed of 1.75, 1.50, 1.25 and 1.00 km/h, respectively.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on actual field capacity**

The data in Fig. 6 shows the relationship between actual field capacity and machine forward speed at different intra-row hill spacing, and seedling cross-section area. The figure shows that increasing the machine forward speed and intra-row hill spacing tends to increase actual field capacity. This may be attributed to the increase in the theoretical field capacity and decrease in the lost time in seedlings feeding.

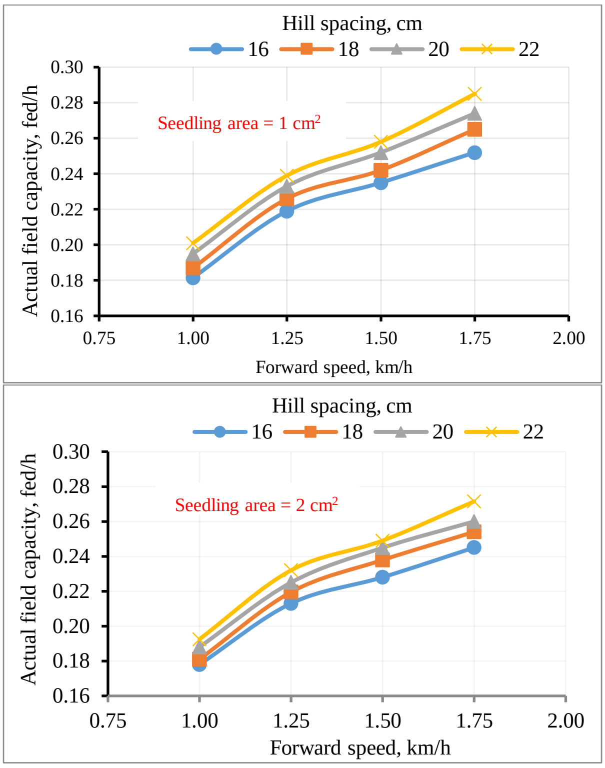


Fig. 6. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on actual field capacity
Source: Authors' determination.

Whereas, increasing the seedling cross-section area led to a decrease in actual field capacity, this may be attributed to increase in the number of seedling trays needed per feddan, which tends to increase the lost time in seedlings feeding. The presented data shows that, in the case of the seedling cross-section area of 1.00 $cm^2$,increasing forward speed from 1.00 to 1.75 km/h led to an increase in actual field capacity from 0.182-0.252, 0.187-0.265, 0.195-0.274 and 0.201-0.285 fed/h at intra-row hill spacing of 16, 18, 20 and 22 cm, respectively. While,in the case of the seedling cross-section area of 2.00 $cm^2$, increasing intra-row spacing from 16 to 22 cm tends to increase the actual field capacity value from 0.178-0.193, 0.213-0.232, 0.228-0.249, and 0.245-271 fed/h at a forward speed of 1.00, 1.25, 1.50 and 1.75km/h, respectively.

**Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on energy requirements.**

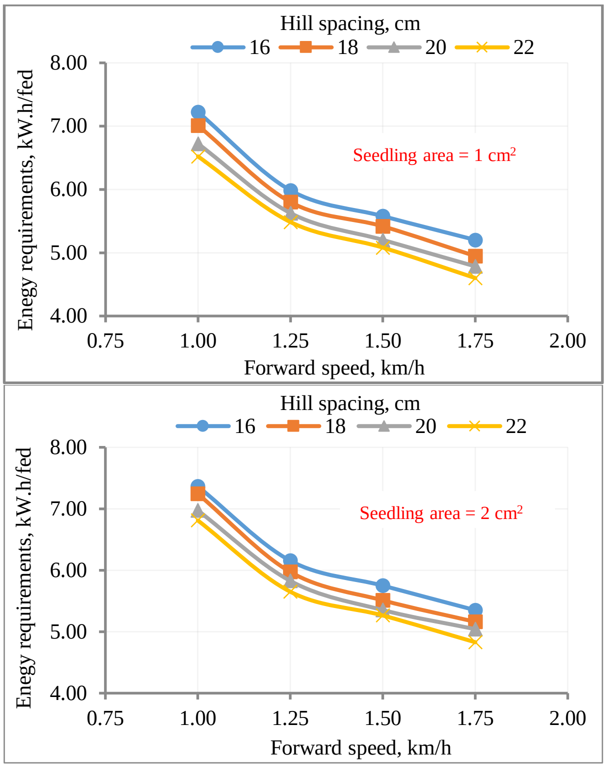


Fig. 7. Effect of machine forward speed, intra-row hill spacing, and seedling cross-section area on energy requirements
Source: Authors' determination.

It is clear from Fig. 7 that energy requirements decreased by increasing machine’s forward speed andintra-row hill spacing and slightly increased by increasing the seedling cross-section area.

Also, in the case of the seedling cross-section area of 1.00 $cm^2$, increasing forward speed from 1.00 to 1.75 km/h led to a decrease in the energy requirements from 7.22-5.20, 7.01-4.94, 6.72-4.78 and 6.52-4.59 at intra-row hill spacing of 16, 18, 20, and 22 cm, respectively. Whereas, increasing seedling cross-section area from 1.00 to 2.00 $cm^2$, the energy requirements increased by an average of 3.3%.

## CONCLUSIONS

The research aimed to manufacture a rice transplanting machine with local materials suitable for small rice holdings. In addition, testing and evaluating themanufactured machine under different operation conditions. The machine was manufactured and tested at the Rice Mechanization Center, Agricultural Engineering Research Institute, Egypt. The machine contains five rows, and the distance between each row is 20 cm.The obtained results indicated that the lowest percentages of missing, floating, and damaged hill were 2.92, 1.83, and 0.27%, respectively. The highest transplanting efficiency and field efficiency were94.98 and 83.75%, respectively, obtained at a machine forward speed of 1.00 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 2.00 $cm^2$. Also, the lowest value of requirement energy was 4.599 kW.h/fed achieved the highest actual field capacity of 0.285 fed/h was obtained at machine forward speed of 1.75 km/h, intra-row hill spacing of 22 cm, and seedling cross-section area of 1.00 $cm^2$.

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# EFFECT OF SUN DRYING AS PRESERVATION METHOD ON APRICOT COLOR SPACES AND SOME CHEMICAL PROPERTIES

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***Abstract***

*The drying characteristics of apricot were determined usingOpen Sun and three Greenhouse Drying (Black Mesh Shading, white and black poly film plastic in as absorbers plate covering greenhouse. pretreatments (control, sucrose syrup and Sodium bicarbonate ) were used before drying conditions at ( Open air , White and Black poly film plastic greenhouse). The color values (L*, a* and b*),beta carotenoids, total soluble sugar and ascorbic acid content were also measured for the different fresh and dried apricot.The fresh apricot fruit initial moisture content was 80.03% d.b. The color values Lightness (L* was 71.14,) Red/Green Value( a* was 21.36) and Blue/Yellow Value (b* was 70.23), Browning Index (BI, was 223.47)hue angle, H$^{o}$ was73.08 and chroma, relative saturation(C was 73.41). Results showed that the moisture, beta carotenoids, total soluble sugar and ascorbic acid were highest in sodium bicarbonate blanched sample and color attributes were found maximum in sodium bicarbonate blanched sample, immediately after dehydration. The values of the dried apricot color spaces (L*, was 14.22, a* was 13.17 and b* was 18.04) while chroma, hue angle, and Browning Index was 22.33, 53.87and 390.12 Black Mesh Shading with pretreatments at Sodium bicarbonate ) There was not much change on the ascorbic acid contents of fresh and dried apricot .*

***Key words***: *apricot, chemical properties, sun drying, colour, pre-treatments*

## INTRODUCTION

Apricot (Prunus armeniaca L.) is a member of the Rosaceae family and is a common fruit due to its special sweetness and color. Annual production exceeds 3.7 million tons [7]. Dried apricot is one of the important traditional export products. In 2019, Egypt shipped 242 tons of apricots. In 2019 alone, interest in Egyptian apricots (fruit) increased, with a change of 19.212% compared to 2018. Apricot exports fell -7.98% between 2017 and 2019, bringing the country $8.17 million in 2019 [22].

Apricots provide significant health benefits because of their high content in antioxidants, primarily phenolic compounds and carotenoids [14].

[17] reported that apricots are rich sources of carotenoids, 50% of which consist of β-carotene, and the carotenoid composition of apricots is unique, being quite different from many of fruits.

The drying process aims to prolong shelf life by reducing physical, chemical, microbiological and enzymatic reaction rates through the removal of the water content, to decrease costs of packaging, warehouse and transportation, and to protect nutritional value [16]. Dried fruits and vegetables are considered an alternative fat-free snack and have been getting a lot of attention lately [6].

Sun-dried fruits and vegetables are one of the oldest methods of food preservation. The reason is that sun drying is a simple method that requires less capital, simple equipment and less energy input. [5].

Before drying, fruits and vegetables are generally subjected to different pre-treatments, such as blanching, osmotic dehydration in sucrose and salty solutions, and immersion in a sodium bisulphite solution [3].

To decrease the effect of spoilage reactions, to facilitate the drying process, to prevent browning, to ensure colour stability, and to improve the overall product quality, some pretreatments are advised [23].

However, to the best of our knowledge, there are no investigations on the effect of dipping the whole apricot in NaCl, sucrose, and sodium bisulphite solutions [3].

The color, beta-carotene, minerals and antioxidant activity of apricots by microwave and hot air treatment were investigated. The system was set to convection mode with air velocity of 1 m s–1, air temperature of 50 °C and 75 °C, microwave mode set to output power of 90 W and 160 W, and microwave mode set to four different combinations of power levels and temperatures (50°C+90W, 50°C+160W, 75°C+90W, 75°C+160W). The color values (L*, b*, ΔEab, h° and C*ab) of dried fruit decreased, while the a* value increased. Dried apricots have a 1.4 to 3.9-fold increase in beta-carotene ratio based on dry matter increase compared to fresh samples [10]**.** [12] investigate the effect of different hot air-drying temperatures and sun drying on quality (color and b-carotene content) of both sulphurated and non-sulphurated apricot. Darkening of the color of fresh apricot when a process of sun drying was applied, was defined as the decreasing L* values from 70.7 to 42.0 and 30.6, and b* values from 50.0 to 25.4 and 11.3 for sulphurated and no sulphurated apricots, respectively in the sun-dried samples. Hunter a* values increased almost two folds, which also shows the darkening of the color. Other researchers also used the LAB method to measure the color change of various crops including sweet potato. The maximum (L* was 74.62 and a* was 15.7) for sweet potato slices were treated while the maximum yellowness (b*) and Browning Index (BI) were 55.46 and 208.29 for untreated sweet potato slices, respectively [20].Color values and b-carotene content of hot air-dried samples were favorable in comparison to air drying. b-carotene content in dried apricots at sun drying 3.87, 3.38 48mg 100 $g^{-1}$ dry matter for sulphurated and no sulphurated apricots, respectively.

Apricots are rich in carbohydrates and minerals, have an amazing color and distinct flavour. The most abundant minerals are potassium and iron. Apricots are an important source of sugars, fibres, proteins, minerals, vitamins A and C, and beta-carotene. Because of its benefits to human health, there is a growing demand for dried apricots all over the world. Moreover, there is a marked interest in polyphenols and carotenoids in this fruit due to its antioxidant activity and ability to prevent chronic diseases. Apricots are characterized by a short harvest season and limited storage time and to provide the market with a wide range of products, saved by drying The drying process aims to extend the shelf life by reducing physical, chemical, microbiological and enzymatic reaction rates by removing the water content and reducing the costs of packaging, storage and transportation and protecting the nutritional value .

However, different drying methods and pre-treatments significantly influence the quality of dried apricot. Therefore, the aim of study was conducted to study the suitable drying methods and pre-treatments for preserving maximum quality traits (beta carotenoids, total soluble sugar and ascorbic acid) and color of dehydrated apricot.

## MATERIALS AND METHODS

The present investigation was carried out in Ras Sadr, Egypt. The aim of the study was to determine the optimum drying conditions for apricots and the optimum initial treatments to obtain better quality.

**Experimental set up**

**Raw Apricot**

Apricot was procured during the month of July 2022. Fresh apricots were washed, halved, divided on three trays made of stainless-steel mesh (covered with a plastic) and then dried by direct exposure to sunlight, with an overall maximum daytime air temperature of around 40°C. After that, apricots were pre-treated by, un treated (**T1**control), and treated with blanched with **1) T2** sucrose syrup (5g in 1liter of hot water at 100°C for 1min).

**2) T3** in Sodium bicarbonate (5g in1liter of hot water at 100°C for 1min), then it put in Sodium chloride and ascorbic acid (5: 20g in 1liter of cold water). Chemicals were purchased from local market for analysis.

Apricot was spread evenly in a single layer on trays. The trays were placed (open air drying; inside three greenhouses (1- Black Mesh Shading greenhouse, 2- white and black poly film plastic greenhouse covering in as absorbers plate. Three trays made of stainless-steel mesh (40 cm x 20 cm) were put in inside drying green house)

During the drying process, the relative humidity of the air was 53 % and average wind speed was 17 m/sec. This traditional sun-drying method is a common process applied by the farmers and the families in several regions in Ras Sadr, aiming to preserve the excess of production and make apricots available for longer periods.

**Moisture content determination**

The moisture content of the dried samples was determined at 78$^{o}$C during 48 h even weight stability, using an air oven set, three replicates carried out for sample according to the Association of Official Analytical [2].

The moisture content of the samples was calculated on a percent dry basis and the average value of the triplicate samples was used.

$$\text{Percent Moisture} = \frac{W_w - W_d}{W_d} \times 100 \text{...........(1)}$$

where: Ww is the initial weight of sweet potato samples (g); Wd is the dry weight of sweet potato samples (g).

**Quality Evaluation of the dried apricot**

**Color properties determination**

The image processing is the conversion of RGB color units to L* a* b* (segment labelling) values necessary for graphics and analysis, respectively. To convert the RGB color space of the image to CIE. Lab color space is necessary to do it in two steps. The first step carries out the RGB to XYZ transformation. And the second step carries out the XYZ → L*a*b* transformation [8].

The color values (CIE ) of the fresh and dried apricot ( *L**, *a** and *b**) were determined, the total color change (ΔE), chroma, hue angle and Browning Index (BI) were calculated after drying from the L*, a* and b* values using these Equations [9].

$$\Delta \mathbf{E} = \sqrt{\Delta \mathbf{L}^2 + \Delta \mathbf{a}^2 + \Delta \mathbf{b}^2} \text{ .................. (2)}$$

$$\Delta L^* = L^*\text{sample} - L^*\text{standard} \text{........... (3)}$$

$$\Delta a^* = a^*\text{sample} - a^*\text{standard} \text{ ............ (4)}$$

$$\Delta b^* = b^*\text{sample} - b^*\text{standard} \text{ ............. (5)}$$

$$\textbf{Hueangle } H^{\circ} = \tan^{-1}\frac{b^*}{a^*} \text{ ......................(6)}$$

$$C^*_{\mathbf{ample}} = \sqrt{\mathbf{a}^* + \mathbf{b}^*} \text{ ............................ (7)}$$

$$\mathbf{BI} = \mathbf{X} - 0.310.17 * 100\% \text{ ...................... (8)}$$

$$\mathbf{X} = \mathbf{a}^* + 1.75\mathbf{L}^* 5.645\mathbf{L}^* + \mathbf{a}^* - 3.012\mathbf{b}^* \text{ ....... (9)}$$

where: L*, a*, and b* sample for the dried sample.

**Ascorbic acid measurements**

Ascorbic acid content was determined as follows [19].

$$\text{Amount of ascorbicacid of sample}\ \frac{\text{mg}}{100\text{g}} = \frac{0.5\text{mg} \times \text{V2} \times 100\text{ml}}{\text{V1 ml} \times \text{V1 5 ml} \times \text{Weight of the sample}} \times 100 \text{ ..............(10)}$$

**Determination of total soluble sugar**

**Total soluble sugars:** TSS were determined by Anthrone reagent. Briefly 8 mg of Anthron reagent was taken in 250 mL beaker and then 40mL $H_2SO_4$ was added to make reaction mixture. After preparing reaction solution, 1 mL from the above prepared solution was taken and mixed with 100 µl samples. Test tubes containing reaction mixture were kept in water bath for 1 hour. Samples were cooled and then absorbance was read at 630 nm [21].

**Measurement of beta carotenoids**

The extraction method followed was as described in the literature with slight modifications [18].

The fruits and vegetables were cut separately and 10g of each fruit and vegetable was weighed and kept separately. The same extraction procedure was followed for all the fruits and vegetables. 10g of the fruit or vegetable was placed in a mortar and crushed with a pestle. A mixture of hexane and acetone in the ratio of 1:1was added into the mortar and the sample was crushed. About 5 ml of acetone was added slowly at regular intervals. The solvents were collected separately and the process was repeated with the sample again for double extraction. The solvents containing carotenoids were filtered through a filter paper and then transferred into a separating funnel. 20ml of distilled water was added along with 20 ml of 10% NaCl solution. The mixture was shaken vigorously and kept aside for the layers to separate. The upper layer contained carotenoids and it was collected separately after the removal of the water and NaCl solution. The extract was collected in tubes. The extraction procedure was repeated thrice for reproducible values and by using a colorimeter, the absorbance of carotenoid was noted at 630 nm.

## RESULTS AND DISCUSSIONS

### Quality of fresh apricot

Physicochemical properties of fresh apricot fruit were indicated in table 1. The average initial moisture content was 80.03% on a dry basis. These findings were consistent with previous studies by [13] who reported the initial moisture content of 85.66 %.

CIE* color values of apricot were in close agreement with a range of L*, 70.7; a*, 6.4; b*, 50.0; C*, 49.3; and h*, 82.7 for [12].

The total soluble sugar content, and beta carotenoidscontent of fresh apricot were **0.474mg/ml and 7.213mg/100g,** respectively. The values of beta carotenoid were quite comparable with the results of [4] who reported 173.2 ± 0.50 and 29.5- 33.5 mg/100 g, respectively for carrot and apricot.

The results of total soluble solids were in close agreement with [1], who reported ranged from 12.67 to 20.00 ◦Brix, for apricot.

The total vitamin C content in the fresh apricot samples was 17 mg/100 g. The finding of this study was not in agreement with values reported by [11] and [17] of 17 and 22.02 mg/100 mL, respectively for apricot.

Table 1. Color space CIELABfor fresh apricot fruit

| Drying methods | Fresh apricot |
|---|---|
| Moisture (d. b.%) | |
| L* | 71.14 |
| a* | 21.36 |
| b* | 70.23 |
| C | 73.41 |
| H° | 73.08 |
| Bi | 223.47 |

Source: Authors' determination.

### Quality of physical properties dehydrated apricot

The effects of pre-treatment on physical properties of dried apricot**.** Color values of L *, a*, b* and total color change for apricot Chroma, hue angle and browning index was measured as illustrated in Table 2.

The color parameters of dried samples are presented in Table 2. The color values of all dried samples are less than the fresh samples. The highest value of lightness (L*) when using for treated with sucrose syrup while was 28.64 at these conditions (Black poly film plastic greenhouse) while at untreated there was 25.09 the maximum value of lightness (L*). Pre-treatment by blanching in sucrose syrup solution results in prevention of enzymatic browning of apricot and it had higher L* (lightness) value; lower Hue, and browning index. This implies that the pretreatment. The Sodium bicarbonate pretreated apricot recorded the highest value of redness (a*) value among the pretreatment methods while was 27.68 while at the untreated apricot of apricot was 26.85 at these conditions (Black poly film plastic greenhouse). The Sodium bicarbonate pretreated apricot recorded the lowest b* value among the pretreatment methods. The values for chroma and hue angle of the dried apricot decreased as compared with fresh samples. Lastly, the values for change color of open air drying higher than the other drying methods**.**

### Quality of chemical properties dehydrated apricot

The influence of drying methods on quality of dehydrated apricot (beta carotenoid, total soluble sugar and ascorbic acid).

Chemical properties of dried apricot were evaluated and the results indicated in Figures 1, 2 and 3.

The changes in total soluble sugar and Ascorbic acid of apricot samples before and after the drying processes as shown in Figures 1 and 2, respectively.

Table 2. Effect pretreatments and drying methods on physical properties of dried apricot

| Drying methods | Pretreatments | L* | a* | b* | C | H° | Bi | ΔE |
|---|---|---|---|---|---|---|---|---|
| **Open air drying** | **T1** | 7.14 | 8.09 | 6.74 | 10.53 | 39.79 | 248.66 | 91.12 |
| | **T2** | 11.24 | 16.69 | 14.32 | 21.99 | 40.62 | 395.20 | 82.07 |
| | **T3** | 11.87 | 13.15 | 14.02 | 19.22 | 46.83 | 343.85 | 82.10 |
| **Black Mesh Shading** | **T1** | 25.09 | 27.55 | 36.07 | 45.39 | 53.33 | 511.81 | 57.67 |
| | **T2** | 27.15 | 23.81 | 37.21 | 44.17 | 57.39 | 463.08 | 55.05 |
| | **T3** | 19.42 | 16.79 | 25.08 | 30.18 | 56.21 | 404.92 | 68.81 |
| **White poly film plastic greenhouse** | **T1** | 11.65 | 13.40 | 14.80 | 19.97 | 48.74 | 392.66 | 81.70 |
| | **T2** | 24.25 | 24.34 | 34.17 | 41.95 | 54.53 | 491.21 | 59.23 |
| | **T3** | 28.11 | 27.68 | 37.29 | 46.44 | 53.41 | 428.43 | 54.56 |
| **Black poly film plastic greenhouse** | **T1** | 8.27 | 12.87 | 11.29 | 17.12 | 41.27 | 447.22 | 86.59 |
| | **T2** | 28.64 | 26.85 | 38.32 | 46.79 | 54.98 | 436.97 | 53.43 |
| | **T3** | 14.22 | 13.17 | 18.04 | 22.33 | 53.87 | 390.12 | 77.66 |

**T1** control **- T2** sucrose syrup (5g in 1liter of hot water at 100 °C for 1min).**T3** in Sodium bicarbonate (5g in1liter of hot water at 100 °C for 1min), then rinsing with Sodium chloride and ascorbic acid (5: 20g in 1liter of cold water).
Source: Own design and results.

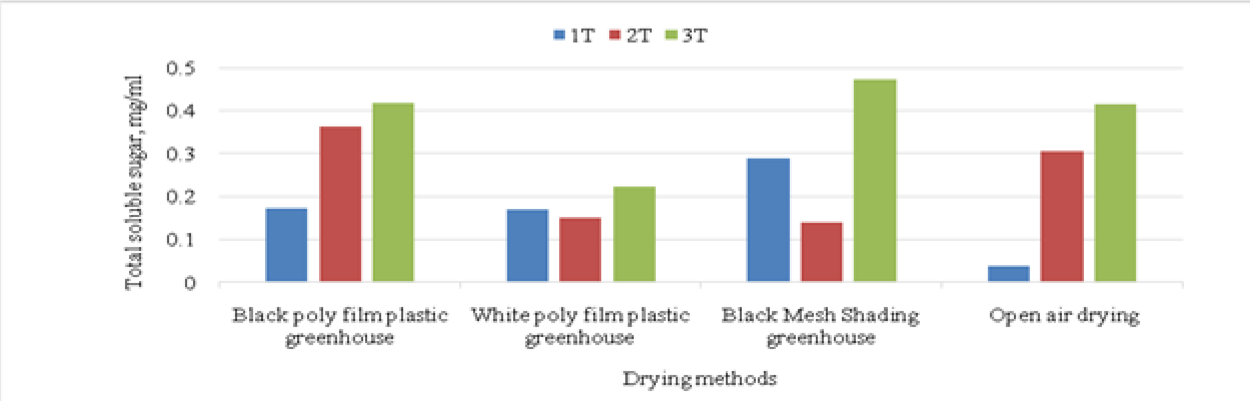


Fig. 1. Effect of pre-treatment methods on Total soluble sugar of dried apricot
Source: Own design and results.

Total soluble sugar ranged from 0.038 to 0.474 mg/ml. The maximum value of Ascorbic acid 8.0108 mg/100g for treated by Sodium bicarbonate, while the minimum value 2.708 mg/100g for treated by sucrose syrup. Beta Carotenoids was assessed before and after the drying processes as illustrated in Figure 3. Pretreatment conditions resulted in reduction in beta carotene content in all cases.

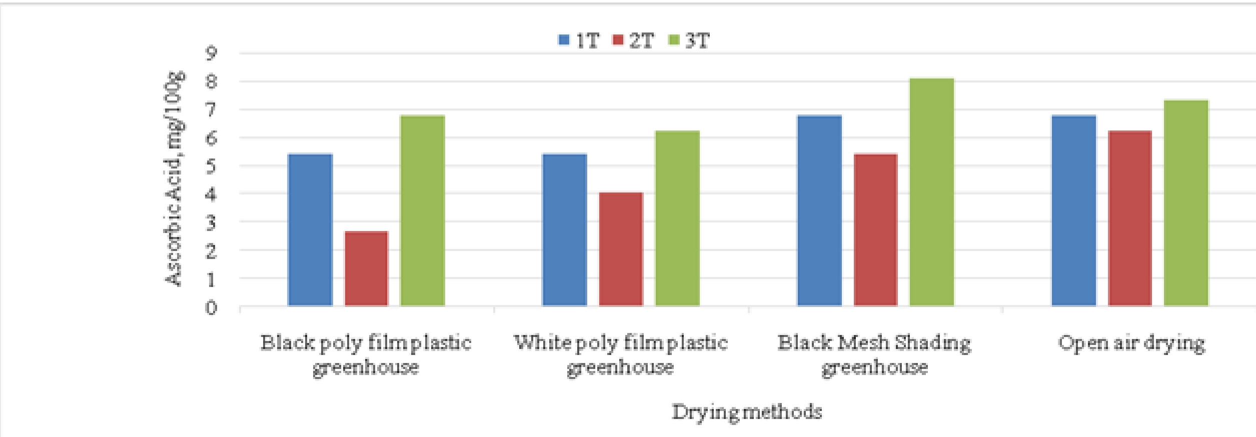


Fig. 2. Effect of pre-treatment methods on Ascorbic Acid of dried apricot
Source: Own design and results.

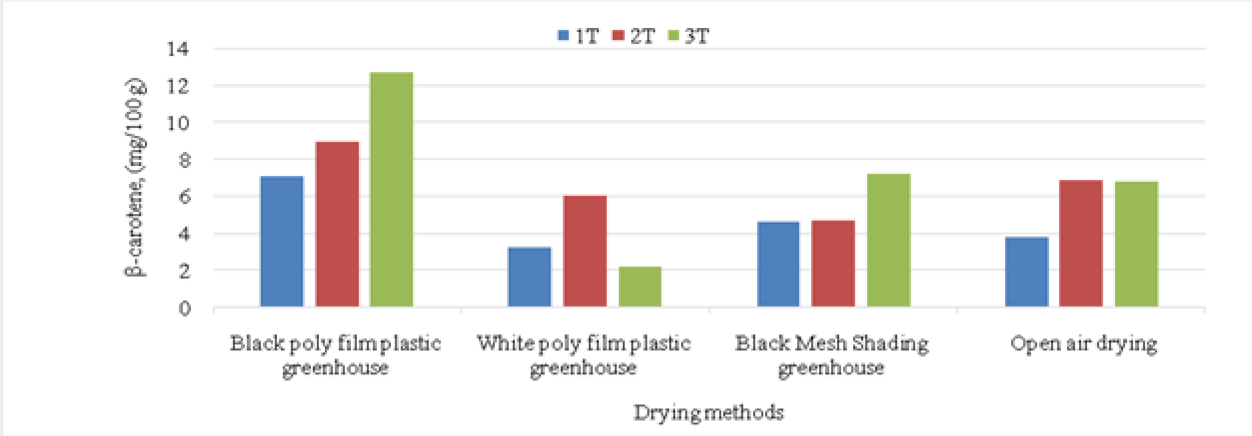


Fig. 3. Effect of pre-treatment methods on β-carotene of dried apricot
Source: Own design and results.

## CONCLUSIONS

Drying of apricots is the preservation method which is highly suitable for Ras Sadr because of the plenty of available sunshine accompanied by low humidity. It is economical and easy as compared with the other methods of preservation as well as there is good quality retention. The different types of solar dryers which are used in Ras Sadr though improved the preservation technique has a tremendous influence on the economy of the small growers. The pre-treated and control apricot were dried with Open air and Greenhouse Drying methods. The apricot was pre-treating with Sodium bicarbonate solution. The pre-treatments and drying methods and their combination had a significant effect on the chemical composition and quality of apricot. Black Mesh Shading greenhouse method had a significant effect on the nutrient retention and a best.

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# COMPATIBILITY OF MILK PRODUCTIVITY AND REPRODUCTIVE CAPACITY IN HOLSTEIN COWS OF DUTCH ORIGIN

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***Abstract***

*The chronology of reproductive indices over 4 years, the interrelationships between milk productivity and reproductive indices in Holstein cows of Dutch origin and the share of action of milk productivity on reproductive indices were investigated. In the specific operating conditions created, the maximum level of milk productivity, at which optimal indicators of reproductive capacity were observed was up to 7,000 kg of milk per lactation. Regression analysis shows that with the increase in service period and calving interval by 1 day, the milk production of the animals will increase by 11.0 kg and 13.1 kg, respectively. The share of action of milk productivity on the coefficient of the reproductive capacity of cows is 0.9008 (P<0.01), on the service-period – 0.147 (P<0.05), on the birth coefficient - 0.0568. For a full realization of the potential of milk productivity and reproductive indices of Holstein cows of Dutch origin, it is necessary to optimize feeding conditions, microclimate, veterinary control, etc. Increasing the duration of the service period and prolonging lactation leads to the slowing down of the reproduction rate of the herd, due to the losses of milk and calves, as a whole on the herd. For this reason, livestock farms should monitor the duration of the service period.*

***Key words***: *Holstein cows of Dutch origin, milk productivity, reproductive capacity, regression analysis, correlation*

## INTRODUCTION

For a long time, selection and breeding activity in the dairy cattle branch was focused on creating animals with increased milk productivity. The reorientation of this vision took place after it was established that milk productivity did not correlate with increased cow longevity [11]. [20] report that in the USA, the amount of milk per lactation, between 1940 and 1990, increased approximately by 3 times (from 2,600 to 8,000 kg)). At the same time, the excessive intensification of a function, in this case lactogenic, does not pass without consequences for other body systems. Researchers and practitioners in many countries indicate a decline in reproductive performance in dairy herds [18; 10] due to an antagonistic relationship between the high level of milk productivity and the functionality of the reproductive system. [3] argue that as herd milk productivity in New York State (USA) increased, the fertility rate after first insemination decreased from 66% (1951) to 40.0 % (1987). [19] mentions that in animals with high productivity, due to the increase in food consumption and milk production, the intensity of metabolism increases significantly, while essentially increasing the catabolism of estrogen and progesterone. Cows with high milk yields have a shorter duration of oestrus, a high incidence of anovulatory cycles [22] and the highest rate of infertility [5; 13; 12], the main cause of significant decrease in fertility being abnormal sexual cycles, expressed, by the absence of basic sexual phenomena: estrus, general reaction, libido and ovulation [18]. If the sexual cycle is disturbed, sterility sets in, so a healthy calf will not be obtained from the cow for a year, and the previous high milk production is no longer important, because the animal is reformed due to infertility and sterility [21].
The genetic and phenotipic correlation between the average 305-days milk yield and the age of first calving is extremely weak and

negative, rG = - 0.257 şi rF = - 0.090 as found for number of 2,237 half sibs, offspring of 989 Friesian bulls and raised in various farms in Romania. And for fat percent as well (rG = - 0.187) and (rF = - 0.032) [16].
In case of the Romanian Brown breed, using 950 lactations, it was found that for the cows whose calving interval was longer than 400 days, milk yield accounted for 4,682.5±124.92 while for the cows whose calving interval varied between 351 and 400 days registered 4,240.0±215.10 kg [17].
An indicator of good adaptability of animals to specific environmental conditions is the combination of high milk productivity and reproductive capacity, serving as a fundamental criterion for breeding breed improvement.
In this order of ideas and in the situation, when about 70% of the herd of cattle for milk production, exploited in the zootechnical units of the republic of Moldova, is constituted of imported animals, in order to develop the strategy of selection and improvement works with this contingent, we proposed to investigate the compatibility of milk productivity with reproductive indices in Holstein cows of Dutch origin.

## MATERIALS AND METHODS

In order to achieve the objective, it was experimented with the population of Holstein cows of Dutch origin, exploited within the production activity: from SRL "Doksancom", Tomai village, Ciadâr-Lunga district. The dynamics of reproductive indices were evaluated: brest restenious (BR), service-period (SP), calving interval (CI), female herd reproductive capacity (CCR) and birth coefficient (CB), interrelationships and regression analysis between reproductive indices according to level milk productivity, and the degree of action of the level of milk productivity on the main reproductive indices.
The direction and strength of the relationship between the main reproductive indices (BR, SP, CCR, CI, CB) and those of milk productivity was determined according to the value of the correlation coefficient (r).
The share (degree) of influence of the level of milk productivity ($\eta_x$) on the general variability ($\eta_y$) of the main reproductive indices ($\eta_z$) (SP, CCR and CI, birth rate) was determined by unifactorial dispersion analysis [15; 2].
The birth coefficient was calculated according to the relationship:

$$BC = \frac{365-SP}{285} * 100 \quad (1)$$

where:
BC – birth coefficient (%);
365 – the number of days in a year;
SP - duration of service period ;
285 – average length of gestation.
The coefficient of reproductive capacity of the female population was calculated according to [6].
The statistical processing of the data was carried out computerized based on Microsoft Office Excel programs, using biometric analysis formulas.
The aim was to obtain position and variation estimators: arithmetic mean - $\overline{X}$ ; standard deviation (mean square deviation) – S; standard deviation of the mean – Sx ; the coefficient of variation - VC% and the correlation coefficient - r.
The authenticity of the obtained results was verified according to the Student criterion - td.

## RESULTS AND DISCUSSIONS

The breeding efficiency of dairy cattle is largely determined by the reproductive intensity of the female herd, which has a direct impact on milk productivity. Brest restenious is of great importance in increasing milk productivity in cows. It is during this period that the cow recovers its energy in relation to the previous lactation and the foundations are laid for the further increase in productivity, the mother's well-being and the product of conception are established, ensuring the favorable progress of parturition, the initiation of successive lactation, the resumption of function ovarian in the postpartum period, etc. In Figure 1, we present the dynamics of the main breeding

indices of the bull herd Holstein breed of Dutch origin.
The analysis of the presented results demonstrates that the duration of dray period as one of the main moments in the exploitation technology of dairy bulls, during 4 years of exploitation has an oscillatory character. The longest duration was in the year 2020, prevailing the best recorded result (year 2021), with a statistically genuine difference of 10.3 days (td =2.8. P<0.05), statistically genuine difference it is also found that compared to the year 2022 of 9.5 days (td=2.7. P<0.01), compared to 2018 the difference is 7 days (td=2.2. P<0.01 ).

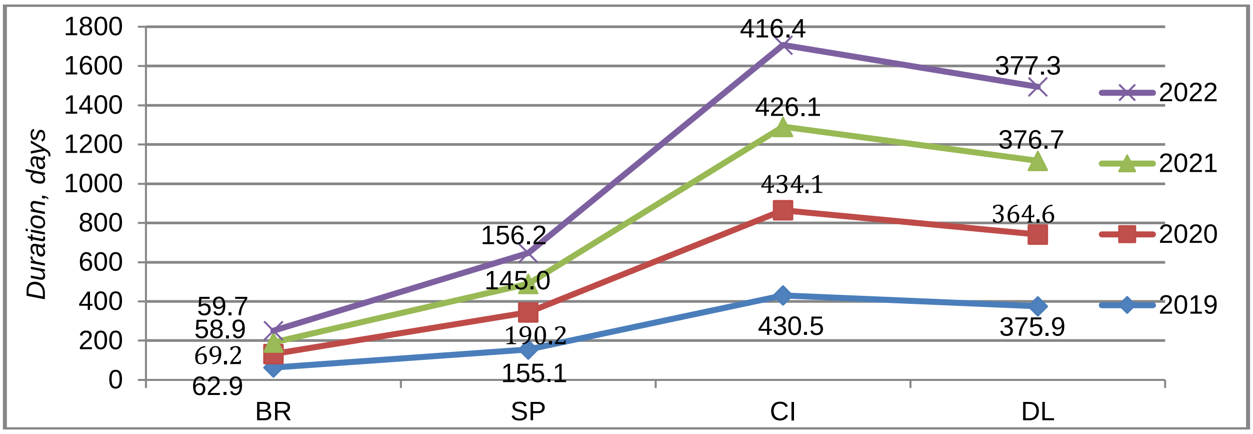


Fig. 1. Chronology of the main reproductive indices and duration of lactation in the Holstein breed cows of Dutch origin
Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

[1] argue that the condition of the cow before calving is of great importance for reproductive intensity. Therefore, in our situation the animals benefited from an optimal period of preparation for the new reproductive cycle.
The service-period determines, first of all, the milk production of cows, as a factor that determines the duration of lactation, but also the period of establishment of pregnancy. The comparative study regarding the service period (Fig. 1) shows that during the 4 years of exploitation of the population of Holstein cows of Dutch origin, under the conditions of SRL "Doksancom", it oscillates within the limit of 145.0 - 190.2 days. The best result was established in the year 2021, being lower compared to 2020 with a statistically genuine difference of 45.2 days (td=4.2. P<0.001). The result recorded in the year 2022 is higher with a genuine statistical difference compared to the year 2021 of 34 days (td = 2.8. P<0.01) and to the result of 2019 by 35.1 days (td=3.3. P<0.001).
Generalizing the analyzed data, we conclude that in all cases the service-period is significantly higher compared to the optimal value allowed, considered 2 - 3 months [4], this being the main condition for accelerating the rate of reproduction of the herd in the household and for increasing the economic efficiency of the branch.
In chronological terms, the statistically genuine increase registered in 2020 may be a consequence of the adapting stress to the new exploitation conditions, and during the next two years it decreases significantly, a fact that witness to a tendency of the animals adaptability.
The duration of the interval between calvings in the dynamics of the years shows a more or less
uniform character, being the highest again in the year 2020, at the opposite extreme is the result recorded in 2022.
The established uniform character, being the highest again the year 2020, at the opposite extreme is the result recorded in 2022.
The established differences are insignificant. A similar character is attested during the duration of lactation.
The results obtained regarding the number of calves obtained per 100 cows per year state that increasing the duration of the service-period significantly decreases the birth rate,

with a very high negative correlation persisting (r= -99.9), which confirms that one of the main conditions for accelerating the reproduction rate of the herd in the household and for increasing the economic efficiency of the branch is that the cows are fertilely inseminated in the first 2–3 months after calving (Fig. 2).

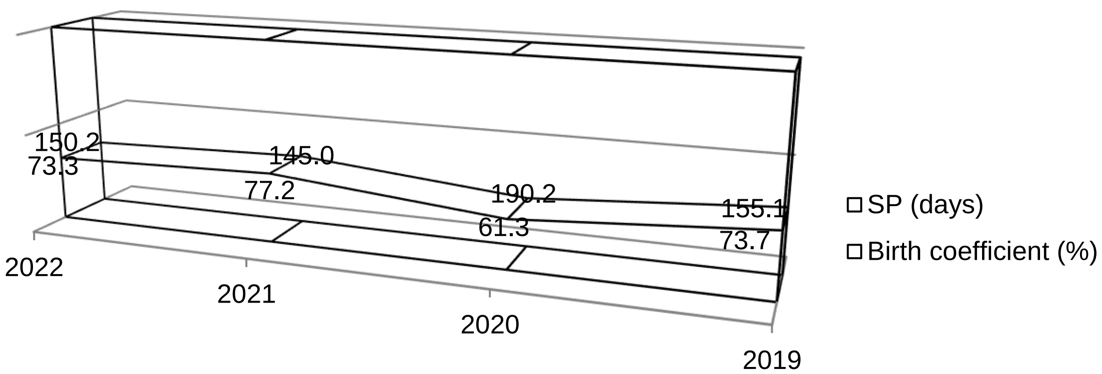


Fig. 2. Chronology of the birth rate in according with the duration of service-period of the Holstein breed cows of Dutch origin
Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

The combination of high milk productivity and reproductive capacity also serves as a fundamental criterion for breeding breed improvement. In Table 1 we present the dynamics of the main reproductive indices according to the level of milk productivity.
The obtained results highlight the presence of a statistically genuine difference in the duration of the service-period depending on the level of milk productivity, starting even with the first two batches of animals. Cows with a level of milk productivity of 5,000-5,999 kg of milk presented the lower service-period (66.6 days),
at the same time the lowest interval between calvings and the highest number of calves obtained per 100 cows (105 %) per year are attested, as a result they also recorded the highest coefficient of use of reproductive capacity.

Table 1. The dynamics of the main reproductive indices according to the level of milk productivity, Holstein breed cows population of Dutch origin

| Productivity classes milk, kg . | SP | | CI | | CCR | | The coefficient of birth, % | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X} \pm S_x$, *days* | Cv, % | $\bar{X} \pm S_x$, *days* | Cv, % | $\bar{X} \pm S_x$, *days* | Cv, % | $\bar{X} \pm S_x$, % | Cv, % |
| 5,000-5,999, (n=11) | 66.6±14.28 | 71.1 | 357.1±13.54 | 12.5 | 1.04±0.04 | 11.6 | 105.0±4.85 | 15.2 |
| 6,000-6,999, (n=16) | 152.1±21.60$^{**}$ | 56.9 | 411.4±22.15 | 19.4 | 0.92±0.05 | 18.5 | 74.6±8.25$^{**}$ | 51.3 |
| 7,000-7,999, (n=16) | 160.1±26.70$^{**}$ | 66.7 | 434.9±29.80$^{*}$ | 25.6 | 0.90±0.02$^{**}$ | 9.2 | 75.1±6.00$^{***}$ | 35.2 |
| 8,000-8,999, (n=29) | 162.2±17.81$^{***}$ | 59.1 | 431.7±16.47$^{**}$ | 18.7 | 0.88±0.03$^{**}$ | 13.5 | 73.9±6.20$^{***}$ | 40.8 |
| 9,000-9,999, (n=24) | 179.5±22.36$^{***}$ | 61.0 | 424.4±20.39$^{**}$ | 19.8 | 0.91±0.03$^{*}$ | 12.6 | 66.5±7.35$^{***}$ | 53.9 |
| 10,000-10,999, (n=21) | 162.2±20.31$^{***}$ | 57.4 | 421.1±19.24$^{*}$ | 18.8 | 0.93±0.04 | 15.4 | 70.0±7.15$^{***}$ | 46.3 |
| 11,000- >, (n=15) | 169.9±27.0$^{**}$ | 53.7 | 400.4±21.20$^{**}$ | 15.0 | 0.93±0.05 | 15.1 | 69.±9.45$^{**}$ | 51.0 |

$^{*}$P<0.05. $^{**}$P<0.01. $^{***}$P<0.001.
Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

The largest service-period was established for the group of cows with the productivity of 9,000 – 9,999 kg of milk per lactation, the differences compared to the other groups, except for the first one, are unauthentic. As the milk productivity increased from 5,000 to

9,900 kg of milk per lactation, the length of the service- period decreased by 2.7 times. The intragroup variation coefficient ranges from 53.3% in animals with a productivity of 11,000 kg of milk per lactation to 71.7% in animals from the first batch.

On the other hand, the interval between calvings was longer in cows with a productivity of 7,000 - 7,999 kg of milk by 10.4 - 77.8 days compared to the rest productivity classes. As the level of milk productivity increases, its value decreases with statistically genuine differences compared to cows with the lowest milk productivity. The coefficient of variation of this index decreased significantly compared to the previous one, oscillating in the range of 12.5% (for animals from the first batch) to 25.6% for those with a productivity level of 7,000 - 7,999 kg of milk. In the rest of the lots, the value of the coefficient of variability occupies an intermediate position. This homogeneity would be due to many factors but also to the fact that the duration of gestation has a constant value (285±2 days). All this contributed to the fact that from cows with a milk productivity level of over 9,000 kg of milk, the biggest losses were from lost calves (-33.5%) .

Regarding the use of the reproductive capacity of the female herd, statistically authentic differences were detected, of different degrees depending on the level of milk productivity. The coefficient of reproductive capacity decreased by 8.4 - 11.6%, compared to the contingent from the batch with productivity up to 4,999 kg of milk per lactation, the coefficient of variation was placed in the limit considered optimal, 9.2% - 18.5%.

In the operating conditions created in SRL "Doksancom", the optimal indicators of reproductive capacity, in Holstein cows of Dutch origin, was at the productivity of 7000 milk per normal lactation,

The results of the correlation analysis between the main reproductive indices and the level of milk productivity are presented in Table 2.

The analyzed data show that in the population of Holstein cows of Dutch origin, between the level of milk productivity and the main reproductive indices, both negative and positive

correlative links are found from very weak, weak to medium. Statistically authentic average positive correlation (td= td=2.1) between the duration of the service period, the value of the birth rate and the milk productivity is found in the group of cows with a productivity greater than 11,000 kg of milk per lactation correlative links are found from very weak, weak to medium.

Table 2. Interrelationships between the level of milk productivity and the main reproductive indices, of Holstein dreed cows population of Dutch origin, r±Sr

| **Productivity classes milk, kg** | **SP, days** | **CB, %** | **CI, days** | **CCR** |
|---|---|---|---|---|
| 5,000-5,999, (n=11) | -0.04±0.32 | -0.13±0.31 | 0.01±0.32 | 0.02±0.32 |
| 6,000-6,999, (n=16) | 0.17±0.25 | -0.39±0.23 | 0.43±0.21 | -0.39±0.22 |
| 7,000-7,999, (n=16) | -0.24±0.24 | -0.22±0.24 | -0.36±0.22 | -0.15±0.25 |
| 8,000-8,999, (n=29) | - 0.34±0.17 | 0.33±0.17 | -0.37±0.16* | -0.22±0.18 |
| 9,000-9,999, (n=24) | 0.22±0.20 | -0.25±0.20 | -0.24±0.20 | 0.13±0.21 |
| 10,000-10,999, (n=21) | -0.16±0.23 | 0.24±0.21 | -0.38±0.19 | 0.26±0.21 |
| 11,000- >, (n=15) | 0.45±0.21* | 0.45±0.21* | -0.41±0.22 | 0.37±0.23 |

*P<0.05

Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

Statistically authentic average positive correlation (td= td=2.1) between the duration of the service period, the value of the birth rate and the milk productivity is found in the group of cows with a productivity greater than 11,000 kg of milk per lactation. Between the duration of the interval between calvings and the level of milk productivity only in cows with the level of productivity 8,000-8,999 kg of milk per lactation the difference is statistically authentic (td=2.3).

The same trend can be seen regarding the interrelationship between the coefficient of utilization of the reproductive capacity and the new milk productivity. To determine the nature of the change, we performed the regression analysis between milk productivity and reproductive indicators. The results are presented in Table 3.

Table 3. Regression coefficients between milk productivity and the main reproductive indicators of Holstein breed cows population of Dutch origin

| Indices | | R |
|---|---|---|
| Milk productivity, kg | Service-period, days | 11.0 |
| Milk productivity, kg | Calving interval, days | 13.1 |
| Milk productivity, kg | Coefficient of birth, % | 2.8 |

Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

According to the obtained data, the regression coefficients between the milk production and the indicators of the functionality of the reproductive apparatus with the increase of the service-period by 1 day, the milk production of the animals will increase by 11.0 kg. An increase in the interval between calvings by 1 day, according to our calculations, leads to an increase in the milk production of a cow by 13.1 kg. However, some authors [7; 9] claim that the significant increase in the duration of the service period and the interval between calvings in order to increase milk productivity will eventually lead to followed a decrease in the amount of milk obtained, as a whole, per herd and the number of calves produced per 100 cows per year.
The share of action of milk productivity on the duration of the service-period is presented in Table 4.

Table 4. The share of action of the level of milk productivity on the general variability of the main reproductive indices

| Breeding indices | $F_{empir.}$ de facto | Action of factors on total dispersion | |
|---|---|---|---|
| | | Intergroup variability, $\eta^2_x$ | Intragroup variability, $\eta_z^2$ |
| SP, days | 3.05* | 0.147 | 0.853 |
| CI, days | 2,1 | 0.1146 | 0.8854 |
| CCR | 142.9*** | 0.9008 | 0.0992 |
| BC, % | 0.96 | 0.0568 | 0.9432 |

Source: SRL "Doksancom", Tomai village, Ciadâr-Lunga district.

The analysis of obtained data indicates that the share of action of milk productivity on the main reproductive indices is different. Thus, the greatest degree of action is found on the reproductive capacity of cows, being also authentic.
In the general variability of the duration of the service-period and the interval between calvings, the share of the factor's action is much smaller compared to that of the reproductive capacity. The lowest level of action is in the case of the birth rate.
Regarding the latter, according to the theory of K. Mather [cited by 14 ], prolificacy having a polygenic character shows continuous variability. In this regard, as a quantitative feature it is characterized by a high variability [8].

## CONCLUSIONS

In the specific operating conditions created, the maximum level of milk productivity, at which optimal indicators of reproductive capacity were observed, in the population of Holstein cows of Dutch origin, was up to 7,000 kg of milk per lactation. The correlative link between milk productivity and reproductive indicators in most cases is weak, the regression being at a high level.
Regression analysis shows that with increasing service-period and calving interval by 1 day, milk production of animals will increase by 11.0 kg and 13.1 kg, respectively, but significant increase in the duration of the SP and CI in order to increase milk productivity will eventually lead to followed a decrease in the amount of milk obtained per herd and the number of calves per 100 cows per year.
The share of action of milk productivity on the coefficient of the reproductive capacity of cows is 0.9008 ($P<0.01$), the service period – 0.147 ($P<0.05$), the birth coefficient - 0.0568.
For a full realization of the potential of milk productivity and reproductive indices of

Holstein cows of Dutch origin, it is necessary to optimize feeding conditions, microclimate, veterinary control, etc.

Increasing the duration of the service period and prolonging lactation leads to the slowing down of the reproduction rate of the herd, due to the losses of milk and calves, as a whole on the herd. For this reason, livestock farms should monitor the duration of the service period.

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# ECONOMIC ANALYSIS OF TOBACCO PRODUCTION IN TURKEY: THE CASE OF USAK PROVINCE

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***Abstract***

*In this study, the cost structure and profitability of tobacco production were examined in the sample of Uşak province. Esme and Ulubey districts in Uşak were the districts with the highest tobacco production. It was determined that 71 tobacco farmers, calculated according to the stratified sampling method, should be interviewed in the villages of these districts. Data were obtained through face-to-face interviews with farmers in the producer survey. Tobacco farming is an important income activity in the region where the family workforce is utilised. Labour force, land rent, and machinery rent were determined as the most significant cost factors in tobacco production. We found that large-scale enterprises are more profitably. In addition, it was determined that the organisation of tobacco farmers was insufficient. With the organisation, farmers will be able to provide the inputs used in tobacco production under more favourable conditions, and the development of marketing opportunities will make a positive contribution.*

***Key words*: *tobacco, production cost, profitability, Turkey***

## INTRODUCTION

About 95% of the world's tobacco production is consumed as cigarettes. In the cigarette industry, Virginia, Burley and Oriental (Turkish type) tobaccos are generally used [18].

According to the data of FAOSTAT [3], tobacco is produced in 122 countries in the world. Of the 6 million tons of tobacco production in the world, 36.3% is produced in China, 12.9% in India, and 11.9% in Brazil. Turkey's contribution to world tobacco production is around 1.3%. In the historical process, the amount of tobacco production in Turkey and its share in the world have decreased since the 2000s.

The highest tobacco production in Turkey is in Adıyaman (it has a 21.9% share of production). Denizli follows this province in the second place with a 17.1% share, and Manisa in the third place with a 17.1% share. The province of Uşak, chosen as the research area, is an important production region where tobacco production in Turkey takes fourth place. The percentage of Uşak province is 9.4%. Turkey's tobacco production decreased by 41% in 2020 compared to 2004. At this point, the contraction in tobacco cultivation areas in Turkey is effective. On the other hand, in the province of Uşak, chosen as the research region, tobacco production increased by 35% in the years examined. It can be said that the increase in tobacco cultivation areas in Uşak province is effective in the increase in production [17].

While tobacco agriculture and trade was at a very important and strategic point for Turkey, became a series of problems in the following years and made it necessary to make some decisions regarding tobacco in various periods. The severe first measure taken by the state in this regard limited the tobacco cultivation areas and started a quota application in 1994. However, in this regard, it was realised that the current stocks did not melt, and the increase could not be prevented in the following years. The agenda created by the negative effect of tobacco products on human health, the prohibition of consumption of tobacco and tobacco products in certain areas in 1996 began a gradual decrease in production. Tobacco, which has a 400-year history in Turkey, gained another dimension with the legal changes made in the 2000s. With Law No. 4733, which entered into force with the announcement of the Official Gazette No. 24635 dated January 9, 2002, support purchases, which are a radical change in the Turkish tobacco industry and an approximate 60-year practice, were abolished, and the contracted production system was started. With the law, tobacco production has become entirely free throughout the country. With this significant change in 2002, there was a remarkable shrinkage in tobacco cultivation areas and a remarkable decline in production [14]. Due to the decrease in production in Turkey, while more than 1 million people made a living from tobacco farming until 2008, the number decreased to 200,000 people in 2020. The privatisation of TEKEL has also been effective at this point.

As a result of the literature review, it was determined that there are many studies on the economic analysis of tobacco production in Turkey [6] [7] [8] [11] [12] [16], but there is no study on the economic analysis of tobacco production in the region where the research was conducted. This study aimed to analyse the cost and profitability of tobacco producers in the province of Uşak, which ranks fourth in tobacco production in Turkey.

## MATERIALS AND METHODS

The main material of the research was the data obtained by the survey method from the producers in the villages producing tobacco in the province of Uşak. Secondary data related to the study are provided by TAPDK, FAO, TUIK, Provincial and District Directorates of Agriculture and Forestry obtained from institutions and organisations. In addition, national and international studies on the subject were also used. The data used in the research belonged to the 2018 production period.

Tobacco producers in Eşme and Ulubey districts in Uşak constitute the main mass of the enterprises from which the data used in the research were obtained. It was obtained by questionnaire method from 71 tobacco producers calculated according to the Stratified Sampling Method [19]. The distribution of sample enterprises according to groups was made using the “Neyman Method” [1]. The research was carried out in Eşme and Ulubey districts where production is the highest in Uşak. Of the tobacco producers interviewed, 66.20% were cultivating in the villages of Eşme district and 33.80% in the villages of Ulubey district. The enterprises were divided into three groups, considering the frequency distribution of the tobacco land they owned. Accordingly, enterprises with 1-14.99 decares of tobacco cultivation area are I. group (28 enterprises), enterprises with 15-30 decares of tobacco cultivation area are II. group (23 enterprises), and enterprises with a tobacco cultivation area of more than 30 decares are also included in III. group (20 enterprises) formed (Table 1).

We used the single product budget analysis method in calculating the cost items of the companies within the scope of the research. Cost elements are divided into two in terms of their economic characteristics. The first is fixed costs that do not depend on the production capacity (rent, insurance, etc.), and the second is the costs that decrease and increase according to the production volume [13]. Production costs in enterprises engaged in tobacco farming were analysed into two main categories variable and fixed costs.

Table 1. Sample size

| Farm groups | Tobacco production area (decares*) | Frequency | Percent |
|---|---|---|---|
| I | <15 | 28 | 39.44 |
| II | 15-30 | 23 | 32.39 |
| III | >30 | 20 | 28.17 |
| Total | | 71 | 100.00 |

*1 decares = 0.1 hectares
Source: Own calculation.

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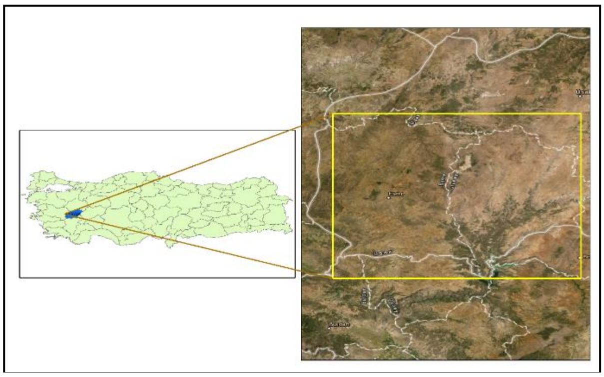
While evaluating the enterprises' annual operating results, GPV (Gross production value), gross profit, Production Costs, Net (Absolute) Profit and Relative Profit indicators were calculated.

The "Neyman Method" we used for sampling takes more samples from the layer with high variance. For this reason, we determined the regional weighted average using the method specified by [4] and [5]. The research area is given in Map 1.



Map 1. Location map of the study areas
Source: Own calculation.

## RESULTS AND DISCUSSIONS

When the products grown by the enterprises were examined, the most cultivated product was tobacco. It was determined that the tobacco-producing area covers 65.72% of the total area in the average of the enterprises and 61.03% of the regional average. The share of tobacco cultivation areas in the total farmland in the farm groups ranged from 47.56% to 75.71% (Table 2).

After tobacco, the most grown product was wheat. Wheat cultivation area constituted 15.44% of the total area in the average of enterprises and 19.49% of the regional average. In the farm groups, the share of wheat cultivation areas in the total farmland ranged from 6.53% to 28.26% (Table 2).

After wheat, the most grown products were barley (5.61%), thyme (4.98%), grapes (3.72%), chickpeas (3.52%) and poppy (1.55%) (Table 2). Enterprises in the region are engaged in dry farming. This limits the pattern of crops they grow.

Table 2. Grown products on farms (%)

| Products | Farm groups (decares) | | | FA* | WA** |
|---|---|---|---|---|---|
| | <15 | 15-30 | >30 | | |
| Tobacco | 47.56 | 66.79 | 75.71 | 65.72 | 61.03 |
| Wheat | 28.26 | 17.25 | 6.53 | 15.44 | 19.49 |
| Barley | 6.94 | 4.71 | 5.46 | 5.61 | 5.71 |
| Thyme | 7.26 | 3.75 | 3.07 | 4.36 | 4.98 |
| Grape | 1.94 | 5.03 | 4.38 | 3.96 | 3.72 |
| Chickpea | 6.35 | 1.82 | 1.54 | 2.86 | 3.52 |
| Poppy | 1.69 | 0.64 | 3.31 | 2.06 | 1.55 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

*FA: Farms Average; **WA: Research Region Weighted Average
Source: Own calculation.

GPV (Gross production value) was calculated as the sum of the values over market prices of the products obtained due to agricultural activities of the enterprises interviewed and the increase in fixtures in the said production activities.

According to the weighted average of the enterprises, we found GPV of 50924.43 TRY obtained from crop production, GPV received from livestock production activity as 5119.89 TRY, GPV obtained from non-operational agricultural activities as 1066.03 TRY and total GPV of 57110. 34 TRY. Accordingly, 89.17% of the GPV obtained by the enterprises in the region was from crop production, 8.96% from livestock production, and 1.87% from non-operational agricultural activities (Table 3).

The third groups were the enterprises that obtained the most GPV from the crop production activity. On the other hand, the enterprises that received the highest GPV from livestock production activities were in the first group. Non-farm agricultural income was in the first group (Table 3).

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Table 3. Gross Production Value of the farm enterprises according to their production activities

| Production activities | Farm groups (decares) | | | FA | WA |
|---|---|---|---|---|---|
| | <15 | 15-30 | >30 | | |
| | Value (TRY*/farms) | | | | |
| Plant | 28,688.74 | 68,128.46 | 96,550.40 | 60,580.95 | 50,924.43 |
| Livestock | 7,517.86 | 2,696.09 | 2,250.00 | 4,471.97 | 5,119.89 |
| Non-operating agricultural income | 1,114.29 | 1,130.43 | 600.00 | 974.65 | 1,066.03 |
| Total GPV | 37,320.88 | 71,954.98 | 99,400.40 | 66,027.57 | 57,110.34 |
| | Percent (%) | | | | |
| Plant | 76.87 | 94.68 | 97.13 | 91.75 | 89.17 |
| Livestock | 20.14 | 3.75 | 2.26 | 6.77 | 8.96 |
| Non-operating agricultural income | 2.99 | 1.57 | 0.60 | 1.48 | 1.87 |
| Total GPV | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

*1 USD = 4.82 TRY for 2018 year
Source: Own calculation.

Variable costs are costs that increase or decrease depending on production volume. These costs arise when production is made and vary depending on output [9].

Another study [9] defines fixed costs as the costs that do not change depending on the production volume and whether or not production is made.

Fixed costs accounted for 59.01% of operating costs and variable costs for 40.99%. We calculated the changing costs as 17,257.13 TRY and the fixed costs as 24,847.50 TRY (Table 4).

The highest share of the changing cost was the wages of temporary workers with 17.19%. The average cost of temporary workers in enterprises was 7,239.87 TRY. Machinery rent was 4,161.77 TRY, the seed-seedling cost was 1,876.74 TRY, agricultural control cost was 1,328.45 TRY, marketing was 1142.33 TRY, fertilisation cost was 844.23 TRY, revolving fund interest was 663.74 TRY (Table 4).

The highest share in fixed costs was permanent-family labour wages with 47.56%. We calculated the permanent-family labour cost as 20,025.72 TRY on average for enterprises. Land rental costs were the second crucial fixed cost element with a share of 10.22% and 4,304.07 TRY. On average, general administrative expenses were 517.71 TRY for enterprises (Table 4).

Production costs were calculated by adding fixed costs and variable costs. The average production costs of the enterprises were 42104.62 TRY (Table 4).

The estimated enterprises' production costs per unit (decare) were calculated as 1,513.34 TRY, and the regional average was 1,663.10 TRY. In the average of enterprises, the total variable costs per decare of tobacco were 620.26 TRY, and the total fixed costs were 893.08 TRY. In the regional average, the variable cost in tobacco production per decare was 631.02 TRY, while the fixed cost was 1,032.08 TRY. The fixed cost was higher than the variable cost in all enterprise groups. The fixed cost in enterprise groups changed between 643.78 TRY and 1,404.62 TRY, and the variable cost changed between 602.45 TRY and 686.25 TRY. As the scale of the enterprises increased, the variable and fixed cost per unit area decreased (Table 5).

Among the cost elements, the most critical was family labour in return for wages. This cost element changed between 501.72 TRY and 1,192.37 TRY in enterprise groups. We calculated 719.77 TRY for the average of enterprises and 842.06 TRY for the regional average. The second important cost element was the temporary labour wage. We have determined that this cost element varies between 192.15 TRY and 309.24 TRY in enterprise groups. We calculated it as 260.22 TRY for the enterprises and 233.80 TRY for the regional average. We found the third important cost factor to land rent. We also determined that this cost element changed between 123.99 TRY and 191.66 TRY in enterprise groups. We found it to be 154.70 TRY in the average enterprises and 171.09 TRY in the region average. We have determined that the fourth important cost factor is machine rent. We found that this cost element varies between 112.99 TRY and 225.64 TRY in enterprise groups. We calculated it as 149.58 TRY for the enterprises and 170.01 TRY for the regional average. In the first group of enterprises, the order of cost per unit area was changing. In this enterprise group, machinery rental is in the third place, and temporary labour wage is in the fourth place among the cost elements (Table 5).

Table 4. Production costs in farms (TRY/farms)

| Production Costs | Farm groups (decares) | | | FA | WA |
|---|---|---|---|---|---|
| | <15 | 15-30 | >30 | | |
| | Cost (TRY/farms) | | | | |
| Machine rental cost | 2,956.64 | 4,408.70 | 5,565.00 | 4,161.77 | 3,786.92 |
| Temporary labour costs | 2,517.78 | 6,040.58 | 15,230.00 | 7,239.87 | 5,207.67 |
| Seed-seedlings costs | 1,169.75 | 1,830.00 | 2,920.27 | 1,876.74 | 1,607.01 |
| Pesticide cost | 848.79 | 1,498.35 | 1,804.60 | 1,328.45 | 1,197.88 |
| Fertilisation cost | 555.02 | 776.21 | 1,327.33 | 844.22 | 721.18 |
| Marketing cost | 598.28 | 1,334.91 | 1,682.53 | 1,142.33 | 994.19 |
| Working capital interest | 345.85 | 635.55 | 1,141.19 | 663.74 | 540.59 |
| Total variable cost | 8,992.12 | 16,524.29 | 29,670.90 | 17,257.13 | 14,055.44 |
| General administration expenses | 269.76 | 495.73 | 890.13 | 517.71 | 421.66 |
| Land rent | 2,511.39 | 4,919.13 | 6,106.50 | 4,304.07 | 3,810.89 |
| Permanent-family labour | 15,623.84 | 21,311.61 | 24,709.56 | 20,025.72 | 18,756.38 |
| Total fixed cost | 18,405.00 | 26,726.47 | 31,706.18 | 24,847.50 | 22,988.93 |
| Total production costs | 27,397.12 | 43,250.76 | 61,377.09 | 42,104.62 | 37,044.37 |
| | The share in the production costs (%) | | | | |
| Machine rental cost | 10.79 | 10.19 | 9.07 | 9.88 | 10.22 |
| Temporary labour costs | 9.19 | 13.97 | 24.81 | 17.19 | 14.06 |
| Seed-seedlings costs | 4.27 | 4.23 | 4.76 | 4.46 | 4.34 |
| Pesticide cost | 3.10 | 3.46 | 2.94 | 3.16 | 3.23 |
| Fertilisation cost | 2.03 | 1.79 | 2.16 | 2.01 | 1.95 |
| Marketing cost | 2.18 | 3.09 | 2.74 | 2.71 | 2.68 |
| Working capital interest | 1.26 | 1.47 | 1.86 | 1.58 | 1.46 |
| Total variable cost | 32.82 | 38.21 | 48.34 | 40.99 | 37.94 |
| General administration expenses | 0.98 | 1.15 | 1.45 | 1.23 | 1.14 |
| Land rent | 9.17 | 11.37 | 9.95 | 10.22 | 10.29 |
| Permanent-family labour | 57.03 | 49.27 | 40.26 | 47.56 | 50.63 |
| Total fixed cost | 67.18 | 61.79 | 51.66 | 59.01 | 62.06 |
| Total production costs | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

Source: Own calculation.

Table 5. Production costs per unit area in farms

| Production Costs | Farm groups (decares) | | | FA | WA |
|---|---|---|---|---|---|
| | I | II | III | | |
| | Cost (TRY per decares) | | | | |
| Machine rental cost | 225.64 | 162.63 | 112.99 | 149.58 | 170.01 |
| Temporary labour costs | 192.15 | 222.83 | 309.24 | 260.22 | 233.80 |
| Seed-seedlings costs | 89.27 | 67.51 | 59.29 | 67.45 | 72.15 |
| Pesticide cost | 64.78 | 55.27 | 36.64 | 47.75 | 53.78 |
| Fertilisation cost | 42.36 | 28.63 | 26.95 | 30.34 | 32.38 |
| Marketing cost | 45.66 | 49.24 | 34.16 | 41.06 | 44.63 |
| Working capital interest | 26.39 | 23.44 | 23.17 | 23.86 | 24.27 |
| Total variable cost | 686.25 | 609.56 | 602.45 | 620.26 | 631.02 |
| General administration expenses | 20.59 | 18.29 | 18.07 | 18.61 | 18.93 |
| Land rent | 191.66 | 181.46 | 123.99 | 154.70 | 171.09 |
| Permanent-family labour | 1,192.37 | 786.15 | 501.72 | 719.77 | 842.06 |
| Total fixed cost | 1,404.62 | 985.90 | 643.78 | 893.08 | 1,032.08 |
| Total production costs | 2,090.87 | 1,595.46 | 1,246.24 | 1,513.34 | 1,663.10 |

Source: Own calculation.

Gross Production Value is the sum of the market prices of the products obtained as a result of agricultural activities in a production branch and the annual productive fixture increases that occur in the said production activities [13]. The GPV was calculated by multiplying the tobacco production by the selling price.

The average GPV per enterprise across all enterprises was determined as 46,628.10 TRY. On the regional average, the GPV was calculated as 39,106.55 TRY. GPV in tobacco production in the region was 1,755.68 TRY per decare, and 1,675.92 TRY in the average of the enterprises interviewed. The GPV value obtained from tobacco per decare in enterprise groups changed between 1,516.12 TRY and 1,931.00 TRY. The GPV was above the operating average in the second group of enterprises and was determined as 1931 TRY per decare (Table 6).

Gross profit is equal to the difference between the GPV and the sum of the variable costs of this branch of production [13]. Gross profit is an important criterion that determines the competitiveness of production activities and shows the success of the enterprise’s organisation [2]. Gross profit was calculated by subtracting the variable costs for tobacco from the GPV derived from tobacco.

The gross profit value in tobacco production in the region was calculated as 1,124.66 TRY per decare. This value was determined as 1,055.66 TRY in the average of the enterprises interviewed. The gross profit value in the second group of enterprises is above the average of the enterprises. The gross profit of the second group of enterprises was calculated as 1,321.44 TRY per decare (Table 6).

Absolute (net) profit is obtained by subtracting the total production costs from the GPV obtained as a result of crop production. This value allows for determining the success of agricultural enterprises within themselves [10]. Net profit was calculated by subtracting the total production costs for tobacco from the GPV from tobacco.

Absolute (net) profit is obtained by subtracting the total production costs from the GPV obtained as a result of crop production. This value allows for determining the success of agricultural enterprises within themselves [10]. Net profit was calculated by subtracting the total production costs for tobacco from the GPV from tobacco.

Net profit was determined as 4,523.47 TRY in the average of enterprises. The net profit obtained from tobacco per decare was 162.58 TRY. The net profit obtained from tobacco per decare was 92.58 TRY in the regional average. In the first group of enterprises, the net profit was calculated as the lowest with -5,495.96 TRY per enterprise. Net profit was determined as 9,096.18 TRY per enterprise in the second group, and 13,292.06 TRY in the third group. The net profit of the enterprises from tobacco per decare was 92.58 TRY on the region average, and 162.58 TRY on the average of the enterprises interviewed (Table 6).

Relative profit represents the ratio of GPV to production costs. In other words, it is an indicator of how much income the farmer earns for the cost of 1 TRY during the economic activity [10]. The relative profit was calculated by dividing the GPV from tobacco by the total production costs for tobacco.

The relative profit in enterprises groups was between 0.80 and 1.22. It was calculated at the rate of 1.11 in the average of enterprises and 1.06 in the average of the region. Relative profit was highest in the third group enterprises (1.22) and lowest in the first group enterprises (0.80) (Table 6).

Another study [15] calculated the relative profit as 1.22 in the average of enterprises and 1.07 in the average of the region. In the study, the author found the relative profit to be highest (1.37) in large enterprises and below one in small enterprises.

The enterprises' unit (kg) tobacco production costs were calculated by proportioning the production costs to tobacco production. The cost of one kg of tobacco was determined as 18.84 TRY in the average of enterprises, and 19.74 TRY in the region average. The highest tobacco production cost was in small-scale enterprises. The sales price per kg of tobacco was 20.87 TRY on the average of the enterprises interviewed, and 20.84 TRY on the region average (Table 6).

The yield obtained from the unit area (decare) was found to be 80.32 kg in the average of enterprises and 84.26 kg in the average of the region. While the group with the highest tobacco yield per unit area among the farm groups was the second group, the group with the least yield was determined to be the farms in the third group (Table 6).

Another study [15] calculated the tobacco yield as 96.55 kg in the average of enterprises and 94.67 kg in the average of the region.

Table 6. Profitability in tobacco production

| Indicators | Farm groups (da) | | | FA | WA |
|---|---|---|---|---|---|
| | I | II | III | | |
| GPV (TRY/farms) | 21,901.15 | 52,346.93 | 74,669.15 | 46,628.10 | 39,106.55 |
| GPV (TRY per decares) | 1,671.43 | 1,931.00 | 1,516.12 | 1,675.92 | 1,755.68 |
| Gross profit (TRY/farms) | 12,909.03 | 35,822.65 | 44,998.25 | 29,370.97 | 25,051.10 |
| Gross profit (TRY per decares) | 985.18 | 1,321.44 | 913.67 | 1,055.66 | 1,124.66 |
| Net profit (TRY/farms) | -5,495.96 | 9,096.18 | 13,292.06 | 4,523.47 | 2,062.17 |
| Net profit (TRY per decares) | -419.44 | 335.54 | 269.89 | 162.58 | 92.58 |
| Relative profit | 0.80 | 1.21 | 1.22 | 1.11 | 1.06 |
| Production cost per kg (TRY) | 25.84 | 17.27 | 17.20 | 18.84 | 19.74 |
| Sale price per kg (TRY) | 20.66 | 20.90 | 20.92 | 20.87 | 20.84 |
| Yield (kg per decares) | 80.92 | 92.38 | 72.46 | 80.32 | 84.26 |

Source: Own calculation.

The relative profit in the examined enterprises changed between 0.29 and 1.99. At this point, some enterprises were below one value of the relative profit (Fig. 1). The labour force was a vital cost to tobacco enterprises in the region. On the other hand, the interviewed enterprises were carrying out tobacco farming by utilising the workforce of their family members. This explains why enterprises continue tobacco farming by using the family workforce, despite the relative profit being less than one.

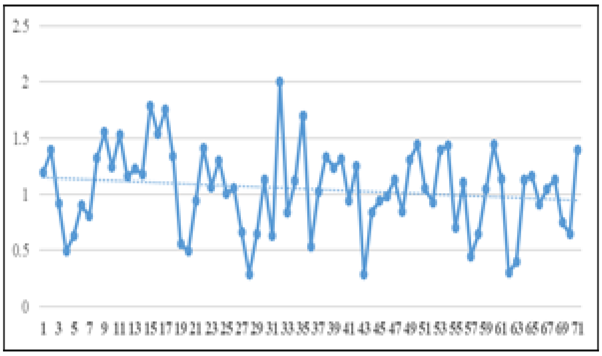

Fig. 1. Relative profit values of tobacco producing farms

Source: Own calculation.

## CONCLUSIONS

Tobacco production was carried out by making intensive use of family labour in the region. This respect explains that the enterprises continue tobacco farming, despite the lack of profitability, especially in small enterprises. The organisation is considered necessary to continue tobacco production activities in the region. With the organisation of the producers, it can be stated that the producers can buy the inputs they use at a more affordable price. At the same time, they will impact price by developing marketing opportunities at the organisational level. This will enable a reduction in tobacco production costs.

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# MODEL FOR MONITORING AND ESTIMATING THE PRODUCTION OF ALFALFA CROP BASED ON REMOTE SENSING

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***Abstract***

*The study used the technique based on remote sensing to analyze and study the dynamics of an alfalfa crop and to estimate the production of fresh biomass in the climatic conditions of the agricultural year 2021-2022. Alfalfa culture in year III, was under non-irrigated cultivated conditions, in the perimeter of DER, University of Life Sciences "King Michael I" from Timisoara, Romania. A period between March 22 and July 23, 2022 was considered, the period during which 14 sets of images from the Sentinel 2 system were acquired. Based on the spectral information contained in the images, the MSAVI, NDMI, NDVI and NBR indices were calculated to characterize the dynamics of the alfalfa crop and estimate the production of fresh biomass. Three harvests (mowing) were made, on May 25 with a production of 10 t ha$^{-1}$ fresh biomass, on July 1 with a production of 7.5 t ha$^{-1}$ fresh biomass and on July 26 with a production of 7.5 t ha$^{-1}$ fresh biomass. Spline models have described most accurately and under statistical safety conditions ($\bar{\varepsilon} = 0.000493$ for MSAVI; $\bar{\varepsilon} = 0.391963$ for NDMI; $\bar{\varepsilon} = 0.002972$ for NDVI; $\bar{\varepsilon} = 0.006759$ for NBR) the dynamics of the indices calculated in relation to the time during the study period, also associated with the moments of fresh biomass harvested. The regression analysis facilitated obtaining predictive models of fresh biomass production, under statistical safety conditions (RMSEP=0.019289 for the combination of MSAVI and NDMI). 3D and isoquants graphic models described the variation of biomass production in relation to the pairs of indices used in the analysis.*

***Key words***: *alfalfa, fresh biomass production, indices, prediction model, regression analysis, remote sensing*

## INTRODUCTION

The management of the farm and agricultural crops is based on correct information, in real time for appropriate decisions in relation to the purpose and objectives proposed as well as the identified problem [16, 24, 25]. The methods of obtaining information are diverse, in relation to the category of elements taken into account (ecological, economic, and social) [36, 38].

For the management of agricultural crops, real-time information on the status of plants, the evolution of crops, influencing factors, maintenance or harvesting works, techniques based on remote sensing offer a series of real-time information [5, 8, 33].

Remote sensing has been used in numerous studies for the classification of crops, the evaluation of the vegetation structure, the establishment of certain moments and intervention works, for the monitoring of crops, for the prediction of biomass production or the evaluation of land quality [1, 13, 26].

Fodder crops occupy an important place in order to produce fodder resources for raising animals, and the periodic evaluation of these crops is important in order to establish some maintenance, harvesting, or variation works in relation to different influencing factors [9, 12]. Remote sensing has been used in various studies for mapping and inventorying grassland surfaces [17], grassland management [3, 30], monitoring of fodder resources [11, 15], the influence of fertilizing resources on the improvement of meadow lands [6].

Alfalfa is a crop plant of high importance for the production and quality of fodder, for food security, being cultivated in different regions of the world, with various conditions [37, 39].

At the same time, alfalfa is important for sustainable agriculture systems, in the structure of crops, crop rotations, as a soil-improving plant [10, 35]. Alfalfa is also important for fixing nitrogen through symbiotic means [32], in the context in which the price of fertilizers and fertilizing resources causes their use to be re-evaluated [7, 20].

In the context of the presented aspects, the present study used techniques based on remote sensing to study the dynamics of an alfalfa crop, and to find models for estimating the production of fresh biomass based on specific indices.

## MATERIALS AND METHODS

Through techniques based on remote sensing, the study evaluated the dynamics of an alfalfa crop within DER, University of Life Sciences "King Michael I" from Timisoara, Romania.

The alfalfa crop was in the third year of exploitation, in a non-irrigated culture system.

In order to evaluate the dynamics of the alfalfa crop, satellite images were taken from the Sentinel 2 system [23], between March 22, 2022 and July 23, 2022, at different time intervals, correlated with the harvesting of fresh food production. 14 sets of satellite images were retrieved, and specific indices were calculated based on the spectral information, MSAVI [27], relation (1), NDMI [34, 40], relation (2), NDVI [31], relation (3) and NBR [19] in order to characterize the alfalfa crop and to predict the production of fresh biomass.

$$MSAVI = \frac{2\,NIR + 1 - \sqrt{(2\,NIR+1)^2 - 8(NIR - Red)}}{2} \qquad (1)$$

$$NDMI = \frac{NIR - SWIR1}{NIR + SWIR1} \qquad (2)$$

$$NDVI = \frac{NIR - Red}{NIR + Red} \qquad (3)$$

$$NBR = \frac{NIR - SWIR2}{NIR + SWIR2} \qquad (4)$$

To describe the dynamics of the alfalfa crop over time, over the study interval, the variation of the index values in relation to time (T, days) was evaluated. There were three harvests (mowing) of fresh biomass for the alfalfa crop, on May 25 (H1), on July 1 (H2) and on July 26 (H3).

The regression analysis was used to obtain production estimation models based on the calculated index values. For the safety of the obtained results, appropriate statistical parameters were used ($\bar{\varepsilon}$, $R^2$, RMSEP). The software PAST [14] and Wolfram Alpha (2020) [41] were used, and also the EXCEL calculation module for data analysis and the generation of different graphic models.

## RESULTS AND DISCUSSIONS

From the analysis of satellite images, taken from the Sentinel 2 system, between March 22 - July 23, 2022, the spectral information was obtained, and based on the relationships (1) - (4), specific indices were calculated for the characterization, dynamic analysis of alfalfa culture and production estimation, (Table 1, Figure 1).

Table 1. Index values in relation to the date of taking the images, in the study of alfalfa culture

| Data | T (days) | MSAVI | NDMI | NDVI | NBR |
|---|---|---|---|---|---|
| 22.03.2022 | 1 | 0.54943480 | -0.01900972 | 0.27756590 | 0.16938811 |
| 06.04.2022 | 16 | 0.66740014 | 0.10968359 | 0.39805683 | 0.32540163 |
| 14.04.2022 | 24 | 0.71217897 | 0.23053786 | 0.47145179 | 0.41288917 |
| 26.04.2022 | 36 | 0.75626211 | 0.27941614 | 0.51916824 | 0.48118806 |
| 04.05.2022 | 44 | 0.73452243 | 0.26465471 | 0.49366455 | 0.46029426 |
| 19.05.2022 | 59 | 0.63278337 | 0.08275454 | 0.36595634 | 0.31211769 |
| 03.06.2022 | 74 | 0.66394500 | 0.07994425 | 0.38156028 | 0.32348280 |
| 13.06.2022 | 84 | 0.57854357 | -0.03939745 | 0.28642021 | 0.19547576 |
| 20.06.2022 | 91 | 0.57419200 | -0.03811468 | 0.27804945 | 0.21104460 |
| 28.06.2022 | 99 | 0.61339991 | -0.00050141 | 0.31019303 | 0.26416654 |
| 03.07.2022 | 104 | 0.59037569 | 0.00328488 | 0.28227862 | 0.27068291 |
| 10.07.2022 | 111 | 0.60878031 | 0.00371384 | 0.31261114 | 0.24185937 |
| 18.07.2022 | 119 | 0.48549074 | -0.10483241 | 0.18480114 | 0.12739878 |
| 23.07.2022 | 124 | 0.48758671 | -0.09829534 | 0.18700221 | 0.13647699 |

Source: Original data, obtained by calculation.

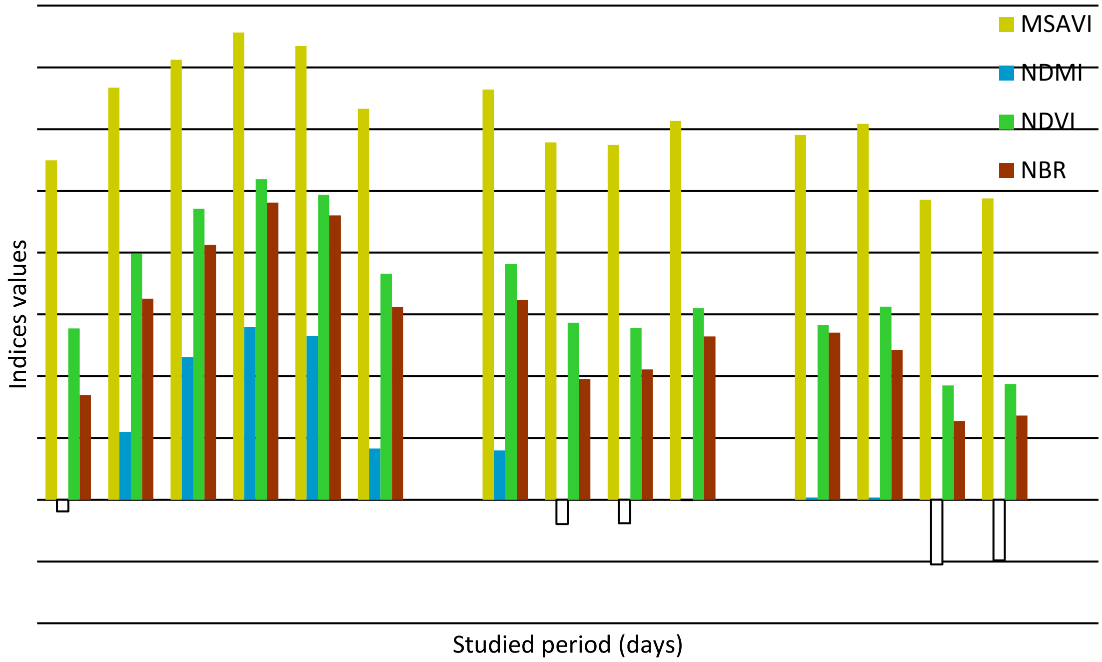


Fig. 1. The graphic distribution of the index values calculated for the dynamic characterization of the alfalfa crop
Source: Original graph.

During the studied period, three harvests were made to harvest the production of green mass in the studied alfalfa culture.

The first harvest was made on May 25 with a production of 10 t of green mass/ha, the second harvest was made on July 1 with a production of 7.5 t of green mass/ha, and the third harvest of was done on July 26 with a production of 7.5 t green mass/ha.

The variation of indices calculated on the basis of satellite images, in relation to the vegetation period of the alfalfa crop and the harvest times, was evaluated by appropriate mathematical and statistical methods and it was found that spline models most accurately described the variation of the index values in study conditions.

In the case of approaching each index through spline models, the average error ( $\bar{\varepsilon}$ ) was calculated with a general equation of the type (5).

$$\bar{\varepsilon} = \left(\sum_{i=1}^{n} \varepsilon_i\right) / n = \left(\sum_{i=1}^{n} \left|\frac{ys_i - y_i}{y_i}\right|\right) / n \qquad (5)$$

In the case of the MSAVI index, the variation of the values recorded during the study period and associated with the harvesting moments were described by a spline model, under statistical safety conditions ( $\bar{\varepsilon} = 0.000493$ ) with the presentation of the associated values in Table 2 and the graphic distribution in Figure 2.

Table 2. Values related to the spline model in relation to the MSAVI index

| Trial | | MSAVI | | | |
|---|---|---|---|---|---|
| No | $x_i$ | $y_i$ | $ys_i$ | $e_i$ | $I_{i/1}$ |
| 1 | 1 | 0.54943 | 0.54967 | 0.00044 | 1.00000 |
| 2 | 16 | 0.66740 | 0.66683 | -0.00085 | 1.21315 |
| 3 | 24 | 0.71218 | 0.71337 | 0.00167 | 1.29782 |
| 4 | 36 | 0.75626 | 0.75537 | -0.00118 | 1.37422 |
| 5 | 44 | 0.73452 | 0.73251 | -0.00274 | 1.33264 |
| 6 | 59 | 0.63278 | 0.63779 | 0.00792 | 1.16031 |
| 7 | 74 | 0.66395 | 0.65649 | -0.01124 | 1.19433 |
| 8 | 84 | 0.57854 | 0.58414 | 0.00968 | 1.06271 |
| 9 | 91 | 0.57419 | 0.57689 | 0.00470 | 1.04952 |
| 10 | 99 | 0.61340 | 0.60400 | -0.01532 | 1.09884 |
| 11 | 104 | 0.59038 | 0.60313 | 0.02160 | 1.09726 |
| 12 | 111 | 0.60878 | 0.59222 | -0.02720 | 1.07741 |
| 13 | 119 | 0.48549 | 0.50197 | 0.03395 | 0.91322 |
| 14 | 124 | 0.48759 | 0.48051 | -0.01452 | 0.87418 |

$\bar{\varepsilon} = 0.000493$

Source: Original data, obtained by calculation.

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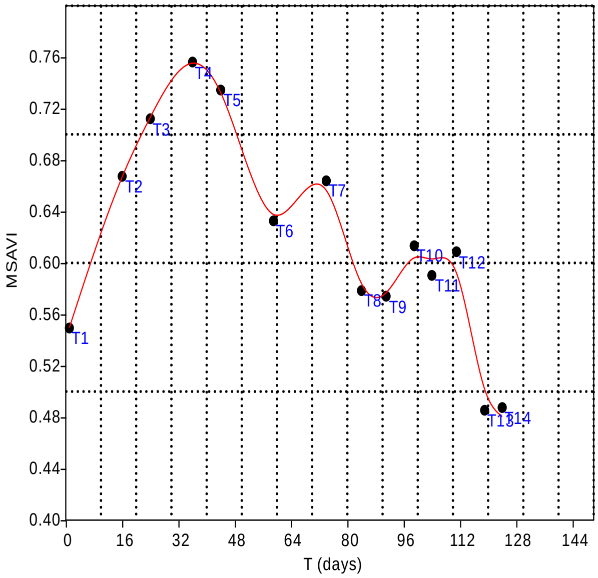


Fig. 2. Spline model for MSAVI variation during the study period
Source: Original graph.

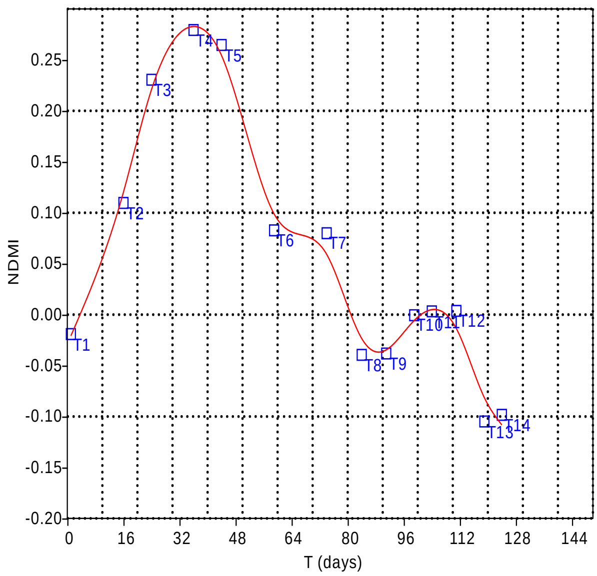


Fig. 3. Spline model for the NDMI variation during the study period
Source: Original graph.

In the case of the NDMI index, the variation of the values recorded during the study period, associated with the harvesting moments of the biomass production, were described by a spline model, under statistical safety conditions ( $\bar{\varepsilon} = 0.391963$ ) with the presentation of the associated values in Table 3 and the graphic distribution in Figure 3.

In the case of the NDVI index, the variation of the values of this index recorded during the study period, associated with the harvesting moments of the biomass production, were described by a spline model, under statistical safety conditions ( $\bar{\varepsilon} = 0.002972$ ) with the presentation of the associated values in Table 4 and the distribution graphics in Figure 4.

Table 3. Values related to the spline model in relation to the NDMI index

| Trial | | NDMI | | | |
|---|---|---|---|---|---|
| No | $x_i$ | $y_i$ | $ys_i$ | $e_i$ | $I_{i/1}$ |
| 1 | 1 | -0.01901 | -0.02075 | 0.09169 | 1.00000 |
| 2 | 16 | 0.10968 | 0.12026 | 0.09646 | -5.79482 |
| 3 | 24 | 0.23054 | 0.22084 | -0.04208 | -10.64135 |
| 4 | 36 | 0.27942 | 0.28280 | 0.01210 | -13.62695 |
| 5 | 44 | 0.26465 | 0.25431 | -0.03907 | -12.25413 |
| 6 | 59 | 0.08276 | 0.09890 | 0.19507 | -4.76548 |
| 7 | 74 | 0.07994 | 0.05921 | -0.25937 | -2.85303 |
| 8 | 84 | -0.03940 | -0.02334 | -0.40765 | 1.12451 |
| 9 | 91 | -0.03812 | -0.03450 | -0.09492 | 1.66227 |
| 10 | 99 | -0.00050 | -0.00562 | 10.20400 | 0.27070 |
| 11 | 104 | 0.00328 | 0.00492 | 0.49761 | -0.23705 |
| 12 | 111 | 0.00371 | -0.01353 | -4.64425 | 0.65215 |
| 13 | 119 | -0.10483 | -0.08140 | -0.22350 | 3.92237 |
| 14 | 124 | -0.09830 | -0.10826 | 0.10138 | 5.21660 |

$\bar{\varepsilon} = 0.391963$

Source: Original data, obtained by calculation.

Table 4. Values related to the spline model in relation to the NDVI index

| Trial | | NDVI | | | |
|---|---|---|---|---|---|
| No | $x_i$ | $y_i$ | $ys_i$ | $e_i$ | $I_{i/1}$ |
| 1 | 1 | 0.27757 | 0.27734 | -0.00083 | 1.00000 |
| 2 | 16 | 0.39806 | 0.39993 | 0.00470 | 1.44202 |
| 3 | 24 | 0.47145 | 0.47030 | -0.00244 | 1.69575 |
| 4 | 36 | 0.51917 | 0.51882 | -0.00067 | 1.87070 |
| 5 | 44 | 0.49366 | 0.49052 | -0.00636 | 1.76866 |
| 6 | 59 | 0.36596 | 0.37290 | 0.01896 | 1.34456 |
| 7 | 74 | 0.38156 | 0.37175 | -0.02571 | 1.34041 |
| 8 | 84 | 0.28642 | 0.29390 | 0.02612 | 1.05971 |
| 9 | 91 | 0.27805 | 0.28068 | 0.00946 | 1.01204 |
| 10 | 99 | 0.31019 | 0.29926 | -0.03524 | 1.07904 |
| 11 | 104 | 0.28228 | 0.29861 | 0.05785 | 1.07669 |
| 12 | 111 | 0.31261 | 0.29118 | -0.06855 | 1.04990 |
| 13 | 119 | 0.18480 | 0.20488 | 0.10866 | 0.73873 |
| 14 | 124 | 0.18700 | 0.17871 | -0.04433 | 0.64437 |

$\bar{\varepsilon} = 0.002972$

Source: Original data, obtained by calculation.

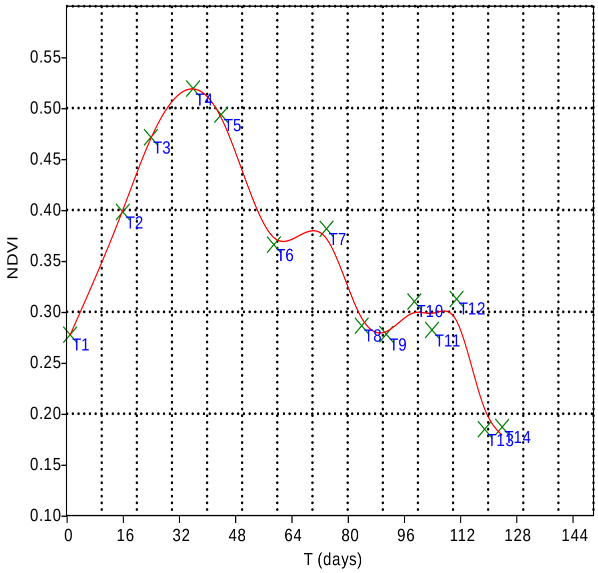


Fig. 4. Spline model for NDVI variation during the study period
Source: Original graph.

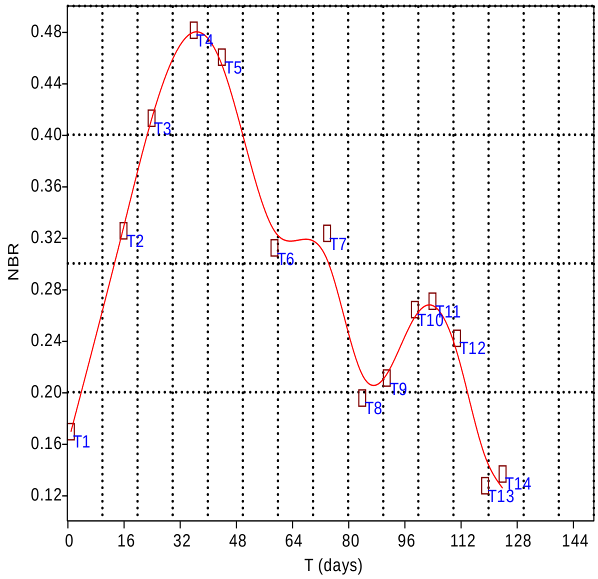


Fig. 5. Spline model for NBR variation during the study period
Source: Original graph.

In the case of the NBR index, the variation of the values of this index recorded during the study period, associated with the harvesting moments of the biomass production, were described by a spline model, under statistical safety conditions ( $\bar{\varepsilon} = 0.006759$ ) with the presentation of the associated values in Table 5 and the distribution graphic in Figure 5.

Table 5. Values related to the spline model in relation to the NBR index

| Trial | | NBR | | | |
|---|---|---|---|---|---|
| No | $x_i$ | $y_i$ | $ys_i$ | $e_i$ | $I_{i/1}$ |
| 1 | 1 | 0.16939 | 0.16922 | -0.00100 | 1.00000 |
| 2 | 16 | 0.32540 | 0.32795 | 0.00784 | 1.93801 |
| 3 | 24 | 0.41289 | 0.41211 | -0.00189 | 2.43535 |
| 4 | 36 | 0.48119 | 0.47965 | -0.00320 | 2.83448 |
| 5 | 44 | 0.46029 | 0.45449 | -0.01260 | 2.68579 |
| 6 | 59 | 0.31212 | 0.32530 | 0.04223 | 1.92235 |
| 7 | 74 | 0.32348 | 0.30303 | -0.06322 | 1.79075 |
| 8 | 84 | 0.19548 | 0.21367 | 0.09305 | 1.26268 |
| 9 | 91 | 0.21104 | 0.21404 | 0.01422 | 1.26486 |
| 10 | 99 | 0.26417 | 0.25845 | -0.02165 | 1.52730 |
| 11 | 104 | 0.27068 | 0.26739 | -0.01215 | 1.58013 |
| 12 | 111 | 0.24186 | 0.23087 | -0.04544 | 1.36432 |
| 13 | 119 | 0.12740 | 0.15023 | 0.17920 | 0.88778 |
| 14 | 124 | 0.13648 | 0.12546 | -0.08074 | 0.74140 |

$\bar{\varepsilon} = 0.006759$

Source: Original data, obtained by calculation.

To estimate the production of alfalfa, fresh mass, the regression analysis was used, which led to equation (6), under statistical safety conditions ($p<0.001$). The values of the equation coefficients are presented in Table 6. For high calculation accuracy, up to 16 decimal places were used for the coefficient values of equation (6). The RMSEP parameter was calculated for each production estimate. Based on the values obtained, it was possible to appreciate that based on the MSAVI and NDMI indices, the most accurate estimate of the production of fresh alfalfa mass was obtained, under the study conditions (RMSEP=0.01928). A 3D model of the variation of fresh alfalfa production was generated, in relation to the values of the MSAVI and NDMI indices (x – MSAVI; y – NDMI), Figure 6 and a graphic model in the form of isoquants, Figure 7.

$$Y_{FB} = ax^2 + by^2 + cx + dy + exy + f \qquad (6)$$

where: $Y_{FB}$ – alfalfa production, fresh biomass;
x, y, - indices considered in equation, table 6
a, b, c, d, e, f – coefficients of the equation (6), table 6

Concerns for the study and estimation of the production of fodder crops through techniques based on remote sensing, or adaptable, have been used for several decades [29] and have been developed and perfected over time, associated with the progress of satellite systems, of specific indices calculations, algorithms and computer systems with high data processing capacity [15, 30].

Table 6. The values of the equation (6) coefficients and RMSEP parameter, in alfalfa fresh biomass estimating

| Equation (6) coefficients | Indexes used | | | | | |
|---|---|---|---|---|---|---|
| | *x*=MSAVI *y*=NDMI | *x*=MSAVI *y*=NDVI | *x*=MSAVI *y*=NBR | *x*=NDMI *y*=NDVI | *x*=NDMI *y*=NBR | *x*=NDVI *y*=NBR |
| a | -73.12800584 | -196.13783570 | -148.36772866 | -194.16199235 | -375.23431017 | -1588.67638576 |
| b | -32.01305530 | -115.99642416 | -79.64529887 | -286.19401227 | -479.32088854 | -700.64570179 |
| c | 85.56554538 | 140.10351110 | 122.06475125 | -141.22553874 | -192.29621357 | 423.87774559 |
| d | -57.64276011 | -107.36109033 | -90.01916256 | 169.41053502 | 220.18985159 | -313.38234413 |
| e | 98.18799891 | 301.10284959 | 217.93284513 | 474.80405985 | 840.45038844 | 2185.71093096 |
| f | 0 | 0 | 0 | 0 | 0 | 0 |
| RMSEP | 0.019289 | 0.022434 | 0.021844 | 0.045899 | 0.266102 | 0.940291 |

Source: Original data, obtained by calculation.

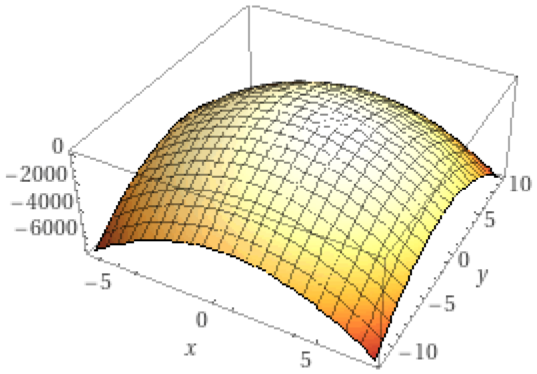


Fig. 6. 3D model of the variation of green mass production in alfalfa in report with MSAVI (x-axis) and NDMI (y-axis)
Source: Original graph.

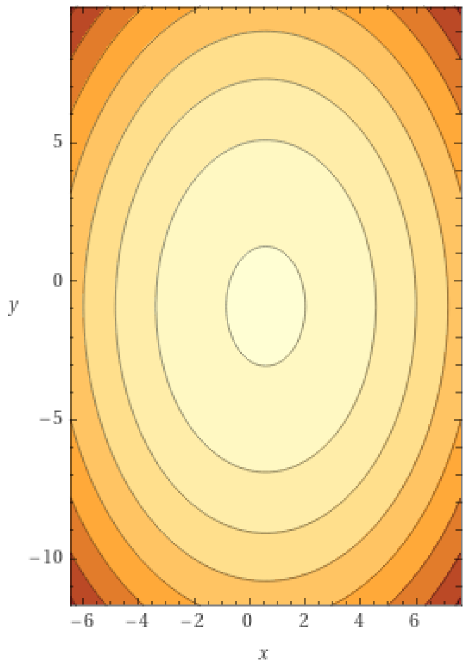


Fig. 7. Model in the form of isoquants regarding the variation of green mass production in alfalfa in relation to MSAVI (x-axis) and NDMI (y-axis)
Source: Original graph.

Good results regarding the prediction of production and quality of forage plants (estimated based on $R^2$, RMSE), based on remote sensing and associated techniques, were communicated for different fodder plants [2, 21, 28]. Spatial variability and alfalfa production were estimated by techniques based on remote sensing, based on specific indices (NDVI, SAVI, NIR reflectance) in safe statistical conditions based on the correlation coefficient (r=0.63 to r=0.69) [18]. The estimation of alfalfa production based on remote sensing techniques was of interest, and good values of production prediction reliability were communicated, assessed based on RMSE (RMSE=1114.0 to RMSE=1237.4 kg/ha) or other statistical safety indices [4, 22].

In the present study, the negative values recorded in the case of the NDMI index (Table 1, Figure 1) highlighted moisture deficits associated with the excessive drought of 2022, with values particularly accentuated in the June-July period. Associated with the respective periods, there was also a decrease in the NDVI values as well as the NBR index, which expresses the vegetation state of the alfalfa crop, respectively the biomass production. Positive correlations were recorded between the respective indices (NDVI, NBR) and NDMI (r=0.996 between NDVI and NDMI, respectively r=0.976 between NBR and NDMI for the period of June; r=0.982 between NDVI and NDMI, respectively r=0.986 between NBR and NDMI for the period of July).

Regarding the estimation of the production based on the indices calculated from the satellite images, and through the regression analysis method, this was possible in conditions of statistical safety, and also, 3D models were obtained in the form of isoquants that described the variation of the production of fresh alfalfa mass in relation to the indicators taken into account.

The authors of the study appreciate that the method can be adapted to other fodder plants in order to monitor crops and estimate production through techniques based on remote sensing.

## CONCLUSIONS

The analysis based on remote sensing, 14 sets of images taken between March 22 - July 23, 2022, agricultural year 2021 - 2022, for an alfalfa crop in the third year of exploitation, non-irrigated system, facilitated the dynamic description of the culture evolution based on the indices specific calculated (MSAVI, NDMI, NDVI, NBR). The NDMI index, through the negative values recorded, highlighted periods of water deficit, in the months of June and July, associated with the actual climatic conditions of the year 2022.
The variation of the indices taken into account in relation to time, during the study period, was most accurately described by spline models. Several combinations of indices were found which, through regression analysis, facilitated the estimation of alfalfa production under statistical safety conditions, and the combination of MSVI and NDMI ensured the most reliable prediction (RMSEP=0.019289).

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# THE SOCIO-ECONOMIC IMPACTS OF MOVEMENT CONTROL ORDER ON RURAL HOUSEHOLDS DURING COVID-19 PANDEMIC IN MALAYSIA

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***Abstract***

*From the outbreak of the COVID-19 pandemic in March 2020 until now, the Malaysian government has implemented various steps in curbing the spread of the virus in order to reduce the infection risk in all regions as well as among rural communities. The implementation of the Movement Control Order (MCO) by the government; designed to control intra– and inter–state and/or district movements and travels has been accepted and accustomed as the new norm in curbing the transmission of infection. This is especially among the vulnerable community groups i.e., elderly people and people with chronic diseases. Although MCO is crucial to curb the virus, this restriction of movement has also inhibited the activities of many important economic sectors especially on transportation of goods and other services. With a consideration that there is a dearth of studies, specifically about the impact of COVID-19 on the socioeconomic condition of the rural communities in specific context; a comprehensive study has been conducted involving 39 selected rural settlements for the whole Peninsular Malaysia. A total of 504 respondents/head of households had participated in the questionnaire survey. Research findings have shown the majority of respondents experienced socioeconomic impacts from MCO and the COVID-19 pandemic, particularly between 50% to 75% income reductions. This is contributed by two main factors: the MCO which hindered them to go out for work and carry out business activities as well as declining sales of produce or livestock. The research findings also reveal that 15% to 25% of the rural communities experienced food supply disruption. This is categorised as low to moderate level. It is important to note that since majority of the respondents are having low income, they are highly vulnerable to this volatile situation. Outcomes of this research could offer meaningful information regarding the current socioeconomic condition of rural communities in relation to the MCO and prolongation of the COVID-19 pandemic. As the way forward, there should be a more inclusive Build Back Better (BBB) strategies for creating a future more resilient rural community to pandemic.*

***Key words*****:** *socioeconomic impact, COVID-19, rural communities, vulnerability, Movement Control Order*

## INTRODUCTION

The coronavirus (COVID-19) which struck in 2020 has placed enormous pressure on the healthcare industry as well as to many other health and socioeconomically related sectors. Proper management of the risk of infection while ensuring public security and health remain strong and intact to endure this global crisis is a major challenge for the Malaysian government [8]. The rapid and widespread transmission of the virus has effectively crippled the entire world. This has caused the sudden closure of state borders as well as prohibitions on interstate or international flight and travel. Such a drastic action had to be taken by the government to reduce the risk of the virus' transmission, alongside ensuring the continued operation of health facilities within their carrying capacities [13].

As a result, the travel restrictions and the simultaneous freezing of economic activities and employee movements in various sectors have shrunk the economic and business performances. Affected workers on the other hands, now need to face the risk of retrenchment and/or salary reductions [1][4][12]. The public as a whole have to adapt their lives to the new normal filled with uncertainties i.e., with two big questions lingering in the background: when will this pandemic be over and will the people be able to rebuilt their live and become resilient after pandemic?

With the consideration that there is a dearth of studies specifically about assessing the impact of COVID-19 on the socioeconomic condition and the situations of the rural communities, a nationwide study has been carried out involving 39 selected rural settlements in Peninsular Malaysia. In total, 504 respondents/head of households have participated in series of field surveys and interviews from June to December 2021.

This article has two parts: first part is the literature review on the COVID-19 pandemic, Movement Control Order (MCO) as well as potential socioeconomic impact on the community livelihoods. The second part of this article shall present the analysis of the impact of COVID-19 on socioeconomic aspects on rural communities in conjunction with the enforcement of MCO by the authority and the conclusion.

**Movement Control Order for Public Safety during Pandemic COVID-19**

In early 2020, both the government and the people of Malaysia are facing double-barrels challenges, namely weaker economic performance and domestic political instability after March 2020 political turmoil which demanded for an appointment of the new prime minister. The new government must also quickly manage the infectious COVID-19 under global economic uncertainties, lower crude oil prices and decline in tourism sector [8] [9].

The Malaysian government has then enforced the first Movement Control Order (MCO), from 18$^{th}$ March 2020 until 12$^{th}$ May 2020. Under the first phase of the MCO, almost all major economic sectors were shut down — with the exception of essential services and resource/food-based sectors. Citizens are ordered to stay home. The restrictions of surrounding outdoor activities and inter-district and state travels then followed suit [9][10].

The first MCO was considered very rigid and adhere to strict measures. As a result, number of daily cases remain under control and within the existing healthcare facility capacities to manage and deliver effective treatment for COVID-19 patients. With the public compliance to the new normal and infection cases that were under control, the government loosened the MCO by implementing the Conditional Movement Control Order (CMCO) [3]. Under CMCO phase, which lasted until 9 June 2020, more economic sectors were allowed to open and limited movements for the public under strict health and safety procedures. The implemented efforts in halting the spread of the virus were received positively by the public and recognized by international bodies, including in conducting tests, close contact detection, quarantine, treatment, and channelling the right information to the frontline works and the public as a whole [2] [7].

With the positive outcomes (and efficacy) shown via the MCO/CMCO and mass vaccination status high percentage of more than 88.0% adult population with completed two doses, the government then launch the National Recovery Plan (NRP) on 15 June 2021 as the nation are to be ready for the endemic stage [5]. Under NRP, all social and economic sectors shall be opened, interstate travel and international movements are allowed. However, the basic '3C principles' must be practiced at all times, which are to avoid: (a) Crowded places, (b) Close conversation and (c) Confined spaces.

**The Impact of the COVID-19 on Rural Livelihood**

COVID-19 in Malaysia has a broad impact on the livelihoods of people in urban and rural areas. With the adoption of new normal as well as strict compliance to SOP and health standards and procedures, the public have experienced both behavioural and lifestyle changes. This in turn has greatly impacted their socioeconomic well-being. Based on the report by the Department of Statistics Malaysia [6], the impact of MCO as well as COVID-19 pandemic can be determined and/or categorised into several societal aspects, which are: (a) Job and business, (b) Education, (c) Health, (d) Security, (e) Welfare, (f) Religion, (g) Social relationship (Table 1).

Table 1. Societal aspects impacted by MCO and COVID-19 pandemic based on literature review

| Societal aspect | Affected group | Strength | Weakness |
|---|---|---|---|
| **Job and business** | • Employers<br>• Government, private sector workers<br>• Business owners<br>• Farmers, fishermen | • Producing disciplined workers<br>• Exploring new knowledge<br>• Increasing the usage of e–commerce<br>• Product marketing assistance<br>• Premise rental fee exemption for small and medium enterprises<br>• Wage subsidies to obtain workers<br>• Additional allowance payment to retain jobs<br>• New e-business platforms (example: e-bazaar) | • Loss of job and income<br>• Decline in demand and sales from wholesalers, business owners<br>• Disturbance while working<br>• Forced closure of business or premise<br>• Wage cuts/salary reduction |
| **Education** | • School students<br>• Higher education students<br>• Teachers, lecturers | • Increasing computer literacy<br>• Learning sessions at home<br>• Bringing students and parents closer together<br>• Improving skills at online teaching | • Limited reference materials<br>• Limited verbal communications<br>• Limited internet access<br>• Amendment of school, exam sessions |
| **Health** | • Working citizens<br>• Senior citizens | • Adequate rest<br>• Healthy diet<br>• Reduction in COVID-19 transmission<br>• Payment exemption for foreigners who have done their COVID-19screening | • Mental and emotional stress<br>• Obesity due to uncontrolled eating habits<br>• Limited supply of food and medicine<br>• Food source being cut off/ disruption of food supply chain |
| **Security** | • All citizens | • Decline in crime rate<br>• Decline in road accidents rate | • Rise in online scammers<br>• Domestic violence and abuse<br>• Homelessness<br>• Malaysians stranded overseas |
| **Welfare** | • All citizens | • One-off, periodic cash assistance<br>• Food basket assistance<br>• Rent assistance(moratorium)<br>• Donation<br>• Identifiability of homeless folk<br>• Subsidized utilities rate | • Late arrival of assistance in rural areas |
| **Religion** | • The citizen, according to religion | • More praying sessions with family | • Places of worship become empty and without any activities/visitors |
| **Social relationship** | • All citizens | • More family bonding time<br>• Unity within the community<br>• Free internet packages | • Communication via the digital realm<br>• Rise in number of births |

Source: Adopted from [6][8].

The literature review process however, identified the lack of existing studies that have being carried out to determine impacts of MCO and COVID-19 pandemic specifically on the livelihoods of rural communities in Malaysia. Even though relevant agencies such as the Department of Statistics and the Ministry of Health provided recent and updated data but overall the data is still general in nature and bias to the urban setting as compared to rural situation.

Several published and referenced studies focus on the rural with regards to impacts of COVID-19 pandemic were obtained. However, the studies only covered sub-components such as a study by Musa & Abdul Rashid [11] on the impact of COVID-19 on the life of a group of small-scale farmers and few other studies which focusing on specific group of a rural community.

The lack of comprehensive study that evaluates the socioeconomic impact of MCO and COVID-19 pandemic on the rural livelihoods has justified this study to be carried out by the authors.

## MATERIALS AND METHODS

### Study Areas

The study area covers only Peninsular Malaysia, specifically 39 selected rural settlements ranges from the main four categories of rural namely traditional villages, structured settlements, estate quarters and Orang Asli villages (Fig. 1). Selection of different types of rural settlements should enable the researchers to conduct detailed investigation and simple comparative analysis.

The design of this study involves a mixed method i.e., a qualitative research based on the case study (descriptive and field observation study), as well as quantitative based on the questionnaire-guided interview. The primary data is gathered through the household survey, using questionnaires involving the heads of households (HoHs) in the research areas. The sampling frame was determined based on the population data provided by the Department of Statistics Malaysia (DoSM), with additional information by the Malaysian Ministry of Education (MOE) Service Circular Number 1/2016 (related to the payment of teachers' allowances stationed in various categories of rural areas). The respondent distribution is based on the enumeration block and housing plot, where each enumeration block consists of 80–120 housing plots. The total population of selected villages were obtained from the DoSM. To get the number of households in each location, data of total population is divided with average household sizes in each state involved. The number of HHs in each location will be used as a weight to calculate the number of samples needed at the village level.

From the total number of households of the rural communities of 229,411, the calculated sample size was 384 HHs (95% confidence level and 5 confidence interval). Taking into account the 30% non-response rate, the minimum sample size was 504 samples.

Based on the identified 504 samples (HoHs) from 39 semi-rural, rural and remote areas in Peninsular Malaysia, a stratified sampling and distribution of samples have been identified namely: 234 HoHs from 17 traditional village locations, 131 HoHs from six structured residence locations, 83 HoHs from five locations of estate quarters, and 56 HoHs from 13 Orang Asli villages.

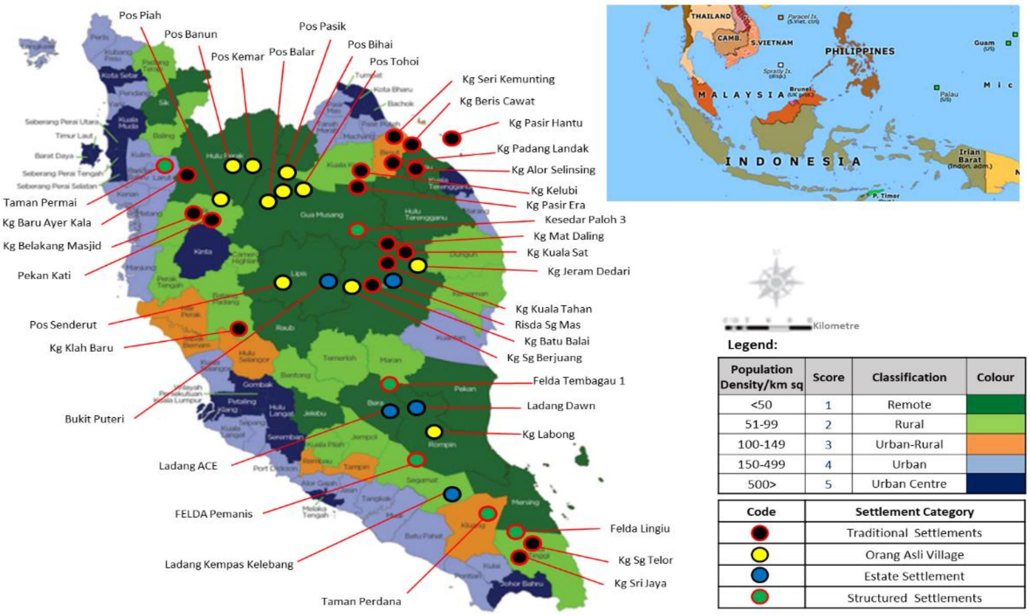


Fig. 1. Distribution of study areas in Peninsular Malaysia based on settlement category.
Source: Research fieldwork [13].

## RESULTS AND DISCUSSIONS

### Profile of Respondents

As shown in Table 2, 56 respondents from the traditional village work as businessmen (23.9%). In the structured residence, most of them work as rubber and palm oil smallholders at 50 (38.2%). All respondents from the estate quarters work in the private sector which is the estate workers. 14 of the Orang Asli respondents are unemployed (25%), 13 are rubber or oil palm smallholders (23.2%) and 11 work in private sectors (19.6%).The mean travelling distance of respondents in rural areas to their workplace is between 7.4km to 10.9km. The minimum distance was 0.5km as stated by respondents from Estate Quarters and Orang Asli Village, while the maximum distance was 102km in Orang Asli Village. The findings also shows that 272 (67.2%) of respondents travel less than 5 km from their house to the workplace. All categories reported that the majority of the respondents have less than 5km distance to their workplace, with 124 respondents from the Traditional Village (68.6%), 64 respondents from the structured residence (61%), 59 from the estate quarters (71.1%) and 29 respondents from the Orang Asli village (69.1%). A total of 244 respondents

(60.2%) use bicycles and/or motorcycles as major transportation modes to their workplace. This consist of 83 respondents from traditional villages (47.4%), followed by 69 respondents from structured residence (65.7%), 67 respondents from estate quarters (80.7%) and 25 Orang Asli (59.5%).

Table 2. Respondents' profile according to categories of rural settlements (n=504)

| | Traditional village | | Structured residences | | Estate quarters | | Orang Asli village | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | N | % |
| **Occupation** | | | | | | | | | | |
| Rubber or Palm Oil smallholders | 51 | 21.8 | 50 | 38.2 | 0 | 0.0 | 13 | 23.2 | 114 | 22.6 |
| Public sector | 20 | 8.5 | 6 | 4.6 | 0 | 0.0 | 5 | 8.9 | 31 | 6.2 |
| Private sector | 40 | 17.1 | 32 | 24.4 | 83 | 10.0 | 11 | 19.6 | 166 | 32.9 |
| Farmers | 7 | 3.0 | 2 | 1.5 | 0 | 0.0 | 6 | 10.7 | 15 | 3.0 |
| Small business operators | 56 | 23.9 | 14 | 10.7 | 0 | 0.0 | 0 | 0.0 | 70 | 13.9 |
| Pensioneer | 5 | 2.1 | 3 | 2.3 | 0 | 0.0 | 1 | 1.8 | 9 | 1.8 |
| Non-timber forest gatherer | 1 | 0.4 | 1 | 0.8 | 0 | 0.0 | 6 | 10.7 | 8 | 1.6 |
| Unemployed | 54 | 23.1 | 23 | 17.6 | 0 | 0.0 | 14 | 25.0 | 91 | 18.1 |
| | | | | | | | | | | |
| **Distance to workplace (in kilometre)** | | | | | | | | | | |
| <5 | 124 | 68.6 | 64 | 61.0 | 59 | 71.1 | 29 | 69.1 | 272 | 67.2 |
| 6-25 | 41 | 23.5 | 31 | 29.5 | 21 | 25.3 | 7 | 16.7 | 100 | 24.7 |
| 25-45 | 10 | 5.8 | 8 | 7.7 | 3 | 3.6 | 3 | 7.2 | 24 | 5.9 |
| >45 | 4 | 2.3 | 2 | 2.0 | 0 | 0.0 | 3 | 7.2 | 9 | 2.2 |
| | | | | | | | | | | |
| **Transportation to workplace** | | | | | | | | | | |
| Walking | 39 | 22.3 | 4 | 3.8 | 2 | 2.4 | 16 | 38.1 | 61 | 15.1 |
| Bicycle/Motorcycle | 83 | 47.4 | 69 | 65.7 | 67 | 80.7 | 25 | 59.5 | 244 | 60.2 |
| Car/Lorry/Bus/Boat | 53 | 30.3 | 32 | 30.5 | 14 | 16.9 | 1 | 2.4 | 100 | 24.7 |
| | | | | | | | | | | |
| **Monthly Gross Income (MYR)** | | | | | | | | | | |
| <1,200.00 | 164 | 70.1 | 39 | 29.8 | 27 | 32.5 | 41 | 73.2 | 271 | 53.8 |
| 1,201.00-2,000.00 | 44 | 18.8 | 51 | 39.0 | 36 | 43.4 | 11 | 19.6 | 142 | 28.2 |
| >2,000.00 | 26 | 11.1 | 41 | 31.3 | 20 | 24.1 | 4 | 7.1 | 91 | 18.1 |
| | | | | | | | | | | |
| **Monthly Gross Household Expenditure (MYR)** | | | | | | | | | | |
| <1,200.00 | 192 | 82.1 | 79 | 60.4 | 74 | 89.1 | 55 | 98.3 | 400 | 79.4 |
| 1,201.00-2,000.00 | 33 | 14.1 | 36 | 27.5 | 7 | 8.4 | 1 | 1.8 | 77 | 15.3 |
| >2,000.00 | 9 | 3.8 | 16 | 12.2 | 2 | 2.4 | 0 | 0.0 | 27 | 5.4 |

Source: Research fieldwork [13].

Majority of the total respondents (53.7%) have below MYR1,200/month gross monthly income, followed by 142 total respondents (28.2%). Only 91 respondents (18.1%) earn monthly income above MYR2,000. Data by category shows that traditional village and Orang Asli village have the higher percentage of gross income below MYR1,200 with 70.1% and 73.2% respectively. For the Monthly Gross Expenditure, the majority of the remote community in the study areas spend less than MYR1,200 involving 400 respondents (79.4%), as compared to 20.6% with spending bigger than MYR1,200. Detail analysis shows that for Orang Asli village, majority of households (98.3%) spent less than MYR1,200/month. Similar pattern was also observed for estate quarters, majority of households (89.1%) spent less than MYR1,200/month, followed by traditional village (82.1%) and structured residences (60.4%).

**Analysis of Economic Effect of MCO and Pandemic COVID-19 on Household Income**

Table 3 presents a comparative analysis on the effect of MCO and pandemic COVID-19 on household income performances which showing more than half of the respondents have experienced income decline (51.2%). This condition is critical particularly in traditional villages where 149 respondents (63.7%) experience an income decline, while 33 respondents (58.9%) are from the Orang Asli village. Estate Quarters has the lowest rate of income decline at only 15 respondents (18.1%). More than half of residents in traditional villages affected during the pandemic have their income reduced, ranging from 50% to 74% reduction. 85 respondents from the traditional village (36.3%) are not affected by the pandemic and MCO.

Table 3. Effects of MCO and Pandemic COVID-19 (household income performances) (n=504)

| | Traditional village | | Structured residences | | Estate quarters | | Orang Asli village | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | N | % |
| **Experience income decline?** | | | | | | | | | | |
| Yes | 149 | 63.7 | 61 | 46.6 | 15 | 18.1 | 33 | 58.9 | 258 | 51.2 |
| No | 85 | 36.3 | 70 | 53.4 | 68 | 81.9 | 23 | 41.1 | 246 | 48.8 |
| | | | | | | | | | | |
| **Percentage of income decline** | | | | | | | | | | |
| 1-24% | 14 | 9.4 | 6 | 9.8 | 4 | 26.7 | 10 | 30.3 | 34 | 13.2 |
| 25-49% | 13 | 8.7 | 13 | 21.3 | 6 | 40.0 | 5 | 15.2 | 37 | 14.3 |
| 50-74% | 76 | 51.0 | 35 | 57.4 | 4 | 26.7 | 15 | 45.5 | 130 | 50.4 |
| 75-100% | 46 | 30.9 | 7 | 11.5 | 1 | 6.7 | 3 | 9.1 | 57 | 22.1 |
| | | | | | | | | | | |
| **Duration of income decline** | | | | | | | | | | |
| <3 months | 18 | 12.1 | 3 | 4.9 | 3 | 20.0 | 14 | 42.4 | 38 | 14.7 |
| 3-6 months | 20 | 13.4 | 10 | 16.4 | 3 | 20.0 | 9 | 27.3 | 42 | 16.3 |
| 6-9 months | 27 | 18.1 | 29 | 47.5 | 1 | 6.7 | 4 | 12.1 | 61 | 23.6 |
| 9-12 months | 4 | 2.7 | 0 | 0.0 | 1 | 6.7 | 0 | 0.0 | 5 | 1.9 |
| >12 months | 80 | 53.7 | 19 | 31.1 | 7 | 46.7 | 6 | 18.2 | 112 | 43.4 |
| | | | | | | | | | | |
| **Reason for income decline** | | | | | | | | | | |
| Not able to go to work | 122 | 81.9 | 37 | 60.7 | 10 | 66.7 | 18 | 32.1 | 187 | 72.5 |
| Retrenchment | 2 | 1.3 | 1 | 1.6 | 0 | 0.0 | 0 | 0.0 | 3 | 1.2 |
| No job offers | 3 | 2.0 | 3 | 4.9 | 0 | 0.0 | 1 | 1.8 | 7 | 2.7 |
| Reduce production | 6 | 4.0 | 10 | 16.4 | 2 | 13.3 | 9 | 16.1 | 27 | 10.5 |
| Reduce non timber product | 0 | 0.0 | 6 | 9.8 | 0 | 0.0 | 3 | 5.4 | 9 | 3.5 |
| Others | 16 | 10.7 | 4 | 6.6 | 3 | 20.0 | 2 | 3.6 | 25 | 9.7 |
| | | | | | | | | | | |
| **Effort to increase/boost income** | | | | | | | | | | |
| Work part-time with private company | 33 | 16.5 | 10 | 9.5 | 5 | 9.3 | 3 | 5.9 | 51 | 12.4 |
| Work in own farm | 24 | 12.0 | 7 | 6.7 | 2 | 3.7 | 16 | 31.4 | 49 | 12.0 |
| Gather forest produce | 10 | 5.0 | 3 | 2.9 | 0 | 0.0 | 14 | 27.5 | 27 | 6.6 |
| No effort/no action taken | 133 | 66.5 | 85 | 81.0 | 47 | 87.0 | 18 | 35.3 | 283 | 69.0 |

Source: Research fieldwork [13].

Similar situation was observed involving respondents in structured residences and Orang Asli villages with 35 respondents (57.4%) and 15 (45.5%) are affected with 50% to 74% income reduction, respectively. Average income reduction is estimated at 53.6% with the lowest decrease of 10% and 100% as the highest level. Comparative analysis also indicated that 112 respondents (43.4%) have had their income declining for more than 12 months since the beginning of the pandemic, followed by prolongation of MCO. On average, the income decline occurred over the past 10 months; the longest duration was 24 months and the shortest was one month. 14 Orang Asli respondents had their income declined for over 3 months (42.4%) followed by 9 respondents (27.3%) for income decline between 3 to 6 months, 6 (18.2%) in more than 12 months. In structured residence, 29 respondents (47.5%) had experienced this situation for about 6 to 9 months. There are various reasons for the income decline among respondents. The COVID-19 pandemic and prolongation of MCO include travel restrictions to their workplace; they cannot continue business operation due to fear of COVID-19 infection (187 respondents or 72.5%). This is a common reason in all four types of rural and remote areas. On the other hand, 27 respondents (10.5%) stated they experienced decline in production (livestock and crop) and drop of sale values. Other reasons also given including retrenchment (1.2%), absence of job offer (2.7%), and decrease in non-timber forest product sales (3.5%). Respondents also requested to state efforts or strategies taken to boost their income during pandemic and MCO. As a result, 51 respondents (12.4%) mentioned they opted for part-time jobs in private companies. This is the highest effort in which 33 (16.5%) at the traditional village, 10 (9.5%) at the structured residence, and 5 (9.3 %) at the estate quarters. Among Orang Asli, their efforts to improve income was derived from few sources including working in farms (31.4%) and collecting non-timber forest products (27.5%). However, most of the respondents (69%) do not have any alternative measures or back-up strategies to boost their income, including 66.5% at the traditional village, 81% at the structured residence, 87% at the estate quarters, and 35.3% at Orang Asli village.

**Impacts of Pandemic COVID-19 and MCO on Food Supply**

Respondents were also asked questions regarding the situation of food supply during pandemic COVID-19 and MCO. As presented in Table 4, majority of respondents stated they did not experience any difficulties to get fresh/wet food during MCO and pandemic COVID-19 (76.4%) as compared to 23.6% that experienced shortage of fresh food throughout the pandemic.

Table 4. Food supply and duration of food shortage during COVID-19

| | **Fresh food** | | **Staple food** | |
|---|---|---|---|---|
| | Total | | Total | |
| | n | % | N | % |
| **Shortage of food** | | | | |
| Yes | 119 | 23.6 | 75 | 14.9 |
| No | 385 | 76.4 | 429 | 85.1 |
| Total | 504 | 100.0 | 504 | 100.0 |
| | | | | |
| **Availability of food** | | | | |
| Not available / scarce | 265 | 52.6 | 289 | 57.3 |
| Available / relatively easy to get | 239 | 47.4 | 215 | 42.7 |
| Total | 504 | 100.0 | 504 | 100.0 |
| | | | | |
| **Duration of shortage** | | | | |
| <1 week | 64 | 53.8 | 39 | 52.0 |
| Between 1-2 weeks | 37 | 31.1 | 16 | 21.3 |
| Between 2-3 weeks | 11 | 9.2 | 18 | 24.0 |
| Between 3-4 weeks | 0 | 0.0 | 0 | 0.0 |
| >4 weeks | 7 | 5.9 | 2 | 2.7 |
| No shortages (1-2 days) | 385 | 76.4 | 429 | 85.1 |
| Total | 504 | 100.0 | 504 | 100.0 |

Source: Research fieldwork [13].

Detail analysis according to different types of villages indicated food supply issue is dire in Orang Asli village as 51.8% of them are affected, followed by 29.1% in traditional villages, 13.7% in structured residence, and only 4.8% in estate quarters.

On the other hand, 85.1% of respondents did not experience shortage of staple/dry food, as compared to 14.9% that experience otherwise. Among those that experience difficulty are in Orang Asli village (44.6%), followed by traditional village (15.8%), structured residence (9.2%), and estate quarters is the lowest at only 1.2% (one person). Most of the fresh/wet food shortage is experienced for less than 1 week in all types of rural areas. Almost 6% of the shortage is prolonged for more than one month, especially in traditional villages (8.8%) and Orang Asli village (3.4%). For estate quarters, the period of fresh/wet food shortage is equally divided between less than one week and between 1 to 2 weeks. On average, days where they are experiencing fresh/wet food shortage is 8 while the minimum day is 1 (all types of residence) and the highest day is in Orang Asli village (74 days). Respondents also mentioned types of fresh/wet food that experience shortages are chicken (37.8%) and fish (34.5%), followed by meat (12.2%), vegetables (11.8%), and fresh fruits (3.8%).

On average, the days of experiencing dry food shortage are 8 while the least day is 1 and the maximum is 30 days. Most of the HoHs (52%) have this problem for less than 1 week in all types of housing areas. The average day in a traditional village is 10 where 40.5% experience it for less than 1 week and 35.1% for 2 to 3 weeks period. None of the interviewees have the problem for the period of 3 weeks to 1 months recorded. Notably, 5.4% from traditional villages have the dry food shortage problem for more than 1 month. Two major types of dry food shortage are rice and cooking oil at 38% and 16.7%, respectively. This is followed by condensed milk (16%), sugar (11.3%), and egg (8.7%). The least recorded types of dry food shortage are biscuit or bread (2.7%), canned sardine (4.7%), and others (2%). There is no shortage of tea and coffee recorded during the study. It is noted that types of dry food shortage in estate quarters are equally distributed between eggs and canned sardines.

## CONCLUSIONS

This study explains the impact of COVID-19 and the MCO, on the socioeconomic of Malaysia's rural communities in general, and in all 39 selected study areas. This study also offered a more detail investigation of socioeconomic impacts based on different category of rural settlements namely traditional village, structured residences, estate quarters and Orang Asli villages. Findings from data analysis indicated that MCO and pandemic COVID-19 have affected rural households including monthly income reductions (higher percentage have experienced up to 74%), income disruption (significant percentage of experience up to >12 months), movement restrictions to workplace and production decline contributing to income disruption etc. The prolongation of MCO and pandemic COVID-19 also disrupted the food supply to rural households. Based on data analysis, the level of food supply disruption can be considered as low to moderate (less than 25% of respondents experience disruption in fresh food and staple food supplies). However, due to high percentage of low-income group, making rural households become highly vulnerable to increase of cost for obtaining fresh and staple food during and after pandemic. There must be more information gathered to lead the establishment of strategies, in order for Build Back Better programmes of rural and vulnerable communities. since the country are now entering the endemic stage where we have to adapt and live together with COVID-19. There is a need for new paradigm in planning and development of rural areas which will reduce their socioeconomic vulnerability and enhance resilience towards pandemic recovery.

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# DEVELOPMENT OF THE WHEAT FLOUR INDUSTRY IN TÜRKİYE AND ANALYSIS OF THE INTERNATIONAL COMPETITIVENESS

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***Abstract***

*This study revealed the development of wheat production and trade in the world and Türkiye, and the level of international competitiveness in wheat flour was determined. Türkiye ranks second in world wheat imports in terms of quantity and fourth in terms of value, and first in wheat flour export. Imported wheat is converted into flour and bakery products, most of which are exported. Türkiye exported 19.04% of world wheat flour in value and 22.45% in quantity. The study calculated competitiveness analysis for 2010-2020, and Balassa's Revealed Comparative Advantage Index (RCA) and Trade Balance Index (TBI) were used in the analysis. The mean index values were calculated as 21.10 in RCA and 0.99 in TBI. As a result of these values, it was determined that Türkiye has a high competitive advantage in wheat flour export and was a net exporter in wheat flour foreign trade.*

***Key words*****:** *wheat flour, competitiveness analysis, revealed comparative advantage, trade balance, Türkiye*

## INTRODUCTION

Wheat is a critical product due to its importance in human nutrition and its contribution to the national economy. It is grown in almost every region of the world. The fact that it is the raw material of bread, one of the basic foodstuffs of people, and it has a large producer mass increases its importance [22]. Wheat is the world's fourth most produced plant product after sugar cane, maize, and rice [19]. It is also used as animal feed and seed [14]. In the 2020/2021 production season, wheat produced in Türkiye was used 11.41% as animal feed and 6.08% as seed [37].

Processing agricultural products to add value is crucial for countries' economies. Wheat is the raw material of pasta, semolina, starch, biscuits, bulgur, tarhana, and flour. [34] emphasized the importance of structural transformation in the development processes of developing countries and stated that for this to happen, it is necessary to create value-added products in basic sectors such as agriculture, industry, and service.

Wheat flour, which has an important share in Türkiye's exports, is one of these value-added products. The export value of wheat flour in Türkiye constitutes 5.24% of the total export value of agricultural products. There are 640 wheat flour factories in Türkiye and the capacity utilization rate of these factories is 51% [35] [13]. In order to use the capacities of the factories effectively, a significant amount of wheat is imported in addition to the wheat produced in the country. The wheat import value constitutes 12.74% of total agricultural products' import value [13]. Türkiye's wheat import is made for the production of flour and bakery products and the export of these products. This import is carried out within the framework of the Inward Processing Regime communiqué numbered 2006/12, published in the Official Gazette dated 20.12.2006 and numbered 26,382 within the scope of the Inward Processing Regime (DIR). DIR has two systems: guaranteeing the taxes to be collected during import (conditional exemption system) and reimbursement of the taxes paid during import (repayment system) for the person with an inward processing permit/processing permit [26].

DIR is important for agro-industrial enterprises. In this way, enterprises are exempt from customs taxes on the supply of raw materials, reduce input costs, and create employment by using their operating capacity more effectively [29]. Advantages of DIR; It creates a cost advantage by providing quality and cheap inputs to enterprises, the economic return of the products obtained from the imported inputs is high thanks to the export condition, and it has effects on increasing the competitiveness of the world countries [25].

The industry of wheat and its finished products, which are of great importance to the Turkish economy, has a problem supplying quality raw materials [6]. In this regard, one of the reasons for Türkiye to import wheat to the sector is the provision of higher quality raw materials in terms of protein ratio, variety characteristics, grain size, environmental conditions, breeding techniques and genotype [7] [27] [21]. The fact that the export price of wheat flour in Türkiye is below the world's average wheat flour price can be explained by this situation. Considering that the main problem in Türkiye is not production but quality, it is important to raise awareness of producers in order to carry out activities to increase quality.

Studies on the wheat and wheat flour industry in Türkiye were found in the literature. Wheat production and marketing in the world [32] [4], wheat and wheat flour quality [8] [6] and Türkiye's wheat foreign trade structure [10] [11] [26] were studied. This study aimed to analyze the international competitiveness of the wheat flour industry, in which Türkiye is the leader. In line with this purpose, firstly, wheat and wheat flour production, export, import and foreign trade balance were presented and discussed with statistical data. Then, the Revealed Comparative Advantage Index (RCA) and Trade Balance Index (TBI) were calculated for 2010-2020.

## MATERIALS AND METHODS

The data for the main material of the study was obtained from the Turkish Statistical Institute (TURKSTAT), the United Nations Food and Agriculture Organization (FAOSTAT), and the International Trade Center (ITC-TRADE-MAP). In addition, sector reports prepared by national and international institutions and organizations related to the subject and academic studies published in scientific journals and books were also used. The data examined within the scope of the study covers the period from 2000-2020. The reason for considering the average of 2000-2002 as the starting year in the examined period was to eliminate factors such as precipitation, drought, disease, and increase and decrease in wheat cultivation areas which are effective in wheat production. The wheat and wheat flour data index was calculated, and the development progress over the years was examined.

The Revealed Comparative Advantages Index (RCA) developed by Balassa [5] and the Trade Balance Index (TBI) were used to analyze the competitiveness of wheat flour in foreign trade.

Balassa's Revealed Comparative Advantage Index was shown in equation 1.

$$RCA_j^i = \frac{x_j^i / \Sigma x^i}{\Sigma x_j^w / \Sigma x^w} \qquad (1)$$

In equality 1; $RCA_j^i$ The Revealed Comparative Advantage Index of country i in product j, $x_j^i$: the export value of product j of country i, $\Sigma x^i$: the total export value of country i, $\Sigma x_j^w$: the total export value of world product j, $\Sigma x^w$: the total export value of the world. A country does not have a comparative advantage if the RCA value is 0-1; a country has a weak comparative advantage if the RCA value is 1-2; a country has a medium comparative advantage if the RCA value is 2-4, and a country has a high comparative advantage if the RCA value is greater than 4 [16].

The Trade Balance Index (TBI), which shows whether the country is a net exporter or a net importer of the relevant product, was shown in equation 2 [38] [17].

$$TBI_j^i = \frac{(x_j^i - m_j^i)}{(x_j^i + m_j^i)} \qquad (2)$$

In equality 2, $TBI_j^i$ is the trade balance that country i has in product j, $x_j^i$ is the export value of the j product of country i, $m_j^i$ is the import value of product j of country. TBI takes a value between -1 and +1, and if this value is negative, it indicates that the country is in a net importer position, and if it is positive, it indicates that it is in a net exporter position [3] [28] [24] [36] [20].

## RESULTS AND DISCUSSIONS

### Developments in wheat and wheat flour production and trade

The average wheat production is influenced by a wide range of factors such as: farm size, crop variety, soil conditions, fertilization level, climate (rainfalls, drought), irrigation, plant protection, farmer training level and experience etc. [30].

World wheat production was 760.9 million tons in 2020. The top five countries that stand out in wheat production were China (17.64%), India (14.14%), Russia (11.29%), the USA (United States) (6.53%) and Canada (4.62%). These countries constituted 54.22% of the total wheat production in the world (Table 1). The highest share belonged to China, which has constantly increased its production over the years. The reason for the continuous increase in wheat production in China; [31] stated that high yields are genetic improvements that provide better resistance to diseases, adaptation to abiotic stresses, and better agricultural practices. In the examined period, from the beginning of the period (2000-2002) until 2020, the highest increase in production was in Russia at 1.95 times. [39] stated in their study that exports were the main incentive to increase wheat production in Russia. It can be said that the export incentive system applied forms the basis of the policies applied for wheat production in Russia. Türkiye ranked 10th in world wheat production. Its share in world wheat production was 2.69%. When the production quantities were analyzed by years, it was determined that Türkiye achieved an increase of 3.36% in 2020 compared to the 2000-2002 period and the changes in production remained constant throughout all periods (Table 1). [9] stated that the increased temperature level in Türkiye adversely affected wheat production and a 1% increase in the average temperature level would reduce wheat production by 0.29% and 0.38%. The study of [12] stated that wheat yield will decrease in Türkiye until 2100.

Table 1. Production quantities of leading wheat producing countries in the world (thousand tons)

| Countries | 2000-2002 | 2005-2007 | 2010-2012 | 2015-2017 | 2018 | 2019 | 2020 | Percent (2020) % | Index (2002-02 = 100) |
|---|---|---|---|---|---|---|---|---|---|
| Chinese | 94,600 | 105,070 | 117,877 | 133,389 | 131,447 | 133,601 | 134,250 | 17.64 | 141.91 |
| India | 72,939 | 71,266 | 87,519 | 92,443 | 99,870 | 103,596 | 107,590 | 14.14 | 147.51 |
| Russia | 44,026 | 47,303 | 45,156 | 73,711 | 72,136 | 74,453 | 85,896 | 11.29 | 195.10 |
| USA | 52,448 | 54,093 | 58,720 | 55,350 | 51,306 | 52,581 | 49,691 | 6.53 | 94.74 |
| Canada | 21,042 | 23,701 | 25,278 | 30,055 | 32,352 | 32,670 | 35,183 | 4.62 | 167.20 |
| France | 35,946 | 35,004 | 37,362 | 36,915 | 35,424 | 40,605 | 30,144 | 3.96 | 83.86 |
| Pakistan | 19,443 | 22,061 | 23,999 | 25,798 | 25,076 | 24,349 | 25,248 | 3.32 | 129.86 |
| Ukraine | 17,367 | 15,528 | 18,313 | 26,280 | 24,653 | 28,370 | 24,912 | 3.27 | 143.44 |
| Germany | 21,759 | 22,316 | 22,992 | 25,165 | 20,264 | 23,063 | 22,172 | 2.91 | 101.90 |
| Türkiye | 19,833 | 19,581 | 20,525 | 21,567 | 20,000 | 19,000 | 20,500 | 2.69 | 103.36 |
| Others | 189,026 | 200,075 | 212,740 | 233,517 | 219,613 | 232,693 | 225,340 | 29.61 | 119.21 |
| Total | 588,429 | 615,999 | 670,480 | 754,190 | 732,140 | 764,981 | 760,926 | 100.00 | 129.31 |

Source: [13].

World wheat export quantity was 117.1 million tons, and export value was 14.68 billion dollars in the 2000-02 average. In 2020, the export quantity increased by 69.55% to 198 million tons and the export value increased by 205.41% to 44.83 billion dollars. In wheat export, the leading countries in terms of export quantity were Russia (18.77%), the USA (13.16%), Canada (13.15%), France (9.97%) and Ukraine (9.09%). These countries constituted 64.14% of the total exports in the world (Table 2). The highest export quantity and value belonged to Russia. It was stated that the highest share in Russia's grain exports is wheat and the changes Russia will make in the wheat market will have a decisive impact on the entire grain industry [1]. In the same period, the country with the highest increase in export quantity and value was Poland. However, this increase was a percentage, and the quantity and value of wheat exports were low compared to other countries. Türkiye's wheat export quantity (0.06%) and the share of export value (0.09%) were quite low compared to other countries. Compared to the average of 2000-02, there was a decrease of 87.24% in the export quantity and 65.06% in the export value in 2020 (Table 2). This situation is because Türkiye's wheat is exported by processing and creating added value. As a matter of fact, Türkiye is the leading country in wheat flour export.

Table 2. Export quantities and values of leading wheat exporting countries

| Countries | 2000-2002 | 2005-2007 | 2010-2012 | 2015-2017 | 2018 | 2019 | 2020 | Percent (2020) % | Index (2002-02 = 100) |
|---|---|---|---|---|---|---|---|---|---|
| | Export Quantity (Thousand tons) | | | | | | | | |
| Russia | 4,105 | 11,489 | 14,374 | 26,529 | 43,966 | 31,873 | 37,267 | 18.77 | 907.84 |
| USA | 25,953 | 27,834 | 28,730 | 24,203 | 22,499 | 27,069 | 26,132 | 13.16 | 100.69 |
| Canada | 16,211 | 16,658 | 17,532 | 21,618 | 22,874 | 22,805 | 26,111 | 13.15 | 161.07 |
| France | 15,778 | 15,663 | 19,299 | 17,796 | 18,940 | 19,957 | 19,793 | 9.97 | 125.45 |
| Ukraine | 3,786 | 3,912 | 5,693 | 16,229 | 16,373 | 13,901 | 18,056 | 9.09 | 476.91 |
| Australia | 15,988 | 11,882 | 19,027 | 18,396 | 12,353 | 9,592 | 10,400 | 5.24 | 65.05 |
| Argentina | 10,287 | 9,925 | 7,970 | 9,226 | 11,725 | 10,543 | 10,197 | 5.14 | 99.13 |
| Germany | 5,384 | 5,126 | 7,359 | 9,625 | 5,229 | 5,551 | 9,259 | 4.66 | 171.97 |
| Kazakhistan | 3,986 | 4,091 | 5,139 | 4,113 | 6,198 | 5,376 | 5,199 | 2.62 | 130.43 |
| Poland | 184 | 478 | 942 | 3,714 | 1,790 | 2,080 | 4,689 | 2.36 | 2548.37 |
| Türkiye | 980 | 344 | 432 | 46 | 70 | 135 | 125 | 0.06 | 12.76 |
| Others | 14,450 | 16,443 | 26,405 | 34,347 | 28,885 | 31,290 | 31,300 | 15.77 | 216.61 |
| Total | 117,091 | 123,846 | 152,903 | 185,841 | 190,902 | 180,171 | 198,527 | 100.00 | 169.55 |
| | Export Value (Thousand dollars) | | | | | | | | |
| Russia | 319,599 | 2,037,160 | 3,421,420 | 4,651,845 | 8,432,493 | 6,403,011 | 7,918,294 | 17.66 | 2,477.57 |
| USA | 3,467,019 | 5,650,944 | 8,686,157 | 5,704,382 | 5,458,267 | 6,265,916 | 6,318,111 | 14.09 | 182.23 |
| Canada | 2,333,256 | 3,270,877 | 5,476,228 | 5,271,564 | 5,711,500 | 5,379,229 | 6,317,889 | 14.09 | 270.78 |
| France | 1,838,418 | 2,869,904 | 5,476,972 | 3,536,176 | 4,111,875 | 4,298,894 | 4,528,591 | 10.10 | 246.33 |
| Ukraine | 313,915 | 479,349 | 1,396,975 | 2,571,804 | 3 ,004,359 | 3,224,194 | 3,594,217 | 8.02 | 1,144.97 |
| Australia | 2,236,248 | 2,142,570 | 5,439,994 | 4,214,392 | 3,036,049 | 2,482,945 | 2,698,498 | 6.02 | 120.67 |
| Argentina | 1,205,664 | 1,589,530 | 2,116,096 | 1,754,148 | 2,419,213 | 2,295,535 | 2,029,494 | 4.53 | 168.33 |
| Germany | 715,057 | 962,917 | 2,057,518 | 1,993,816 | 1,159,547 | 1,235,849 | 2,105,865 | 4.70 | 294.50 |
| Kazakhistan | 365,999 | 637,664 | 1,040,013 | 678,189 | 971,803 | 1,003,207 | 1,137,140 | 2.54 | 310.69 |
| Poland | 20,828 | 87,096 | 268,934 | 751,071 | 403,215 | 427,779 | 1,047,399 | 2.34 | 5,028.80 |
| Türkiye | 113,027 | 46,484 | 79,407 | 19,554 | 24,038 | 48,212 | 39,492 | 0.09 | 34.94 |
| Others | 1,751,000 | 3,077,241 | 7,366,217 | 6,930,186 | 6,333,935 | 6,694,784 | 7,099,117 | 15.83 | 405.43 |
| Total | 14,680,030 | 22,851,737 | 42,825,930 | 38,077,128 | 41,066,294 | 39,759,555 | 44,834,107 | 100.00 | 305.41 |

Source: [13].

World wheat import quantity and value were 116.9 million tons and 16.73 billion dollars on average in 2000-02. In 2020, the quantity of imports increased by 64.99% to 193 million tons, and the import value increased by 191.70% to 48.81 billion dollars. The top five countries leading in wheat imports were Indonesia (5.34%), Türkiye (5.01%), Egypt (4.69%), China (4.23%) and Italy (4.15%), respectively. The highest level of wheat import volume belonged to Indonesia. It was stated that flour consumption in Indonesia, which was 9.9 kg per capita in 2012, was 17.11 kg in 2017 [33]. Therefore, it can be said that the increase in consumption level and the increase in wheat consumption and demand in proportion to the population growth rate are effective in Indonesia's ranking in first place in wheat import. The highest increase in wheat import quantity (12.03 times) and import value (21.63 times) in the analyzed period was in Türkiye (Table 3). It is very important for countries to be self-sufficient in the products they grow. If a country is self-sufficient in its products, it meets domestic demand. Türkiye's self-sufficiency level in wheat in the 2020-2021 market period was 102.3% [37]. This showed that there was no problem with the degree of self-sufficiency. However, the fact that it meets the domestic demand does not mean there is no wheat import. This showed that the imported wheat was processed as wheat flour and exported with added value. Türkiye applies the "Inward Processing Regime" to wheat imports. With this system, input costs are reduced, exports are increased, competitiveness is gained in international markets and export markets are developed in order to realize flour export. In short, there is re-export in the wheat trade.

Table 3. Import quantities and values of leading wheat importing countries

| Countries | 2000-2002 | 2005-2007 | 2010-2012 | 2015-2017 | 2018 | 2019 | 2020 | Percent (2020) % | Index (2002-02 = 100) |
|---|---|---|---|---|---|---|---|---|---|
| | Import Quantity (Thousand tons) | | | | | | | | |
| Indonesia | 3,538 | 4,554 | 5,555 | 9,467 | 10,096 | 10,716 | 10,300 | 5.34 | 291.12 |
| Türkiye | 803 | 841 | 3,676 | 4,522 | 5,782 | 10,005 | 9,659 | 5.01 | 1,202.86 |
| Egypt | 4,961 | 7,311 | 10,607 | 11,577 | 12,505 | 10,424 | 9,043 | 4.69 | 182.28 |
| Chinese | 1,846 | 2,604 | 3,344 | 4,917 | 4,116 | 4,559 | 8,152 | 4.23 | 441.60 |
| Italy | 7,368 | 6,724 | 6,969 | 7,410 | 7,453 | 7,474 | 7,994 | 4.15 | 108.50 |
| Algeria | 5,301 | 5,168 | 6,286 | 8,270 | 8,422 | 6,776 | 7,054 | 3.66 | 133.07 |
| Brazil | 7,037 | 6,052 | 6,215 | 6,020 | 6,817 | 6,576 | 6,160 | 3.20 | 87.54 |
| Philippines | 2,882 | 2,200 | 2,544 | 4,504 | 6,691 | 7,154 | 6,150 | 3.19 | 213.39 |
| Bangladesh | 1,876 | 2,319 | 2,804 | 5,335 | 4,839 | 4,595 | 6,015 | 3.12 | 320.63 |
| Nigeria | 2,269 | 3,322 | 4,026 | 4,736 | 4,810 | 4,660 | 5,903 | 3.06 | 260.16 |
| Others | 78,968 | 82,756 | 101,120 | 116,198 | 116,274 | 106,863 | 116,355 | 60.36 | 147.34 |
| Total | 116,848 | 123,852 | 153,147 | 182,955 | 187,805 | 179,803 | 192,784 | 100.00 | 164.99 |
| | Import Value (Thousand dollars) | | | | | | | | |
| Indonesia | 508,976 | 932,146 | 1,957,371 | 2,706,247 | 2,570,952 | 2,799,261 | 2,616,037 | 5.36 | 513.98 |
| Türkiye | 107,925 | 216,015 | 1,134,703 | 1,013,052 | 1,289,386 | 2,302,225 | 2,334,510 | 4.78 | 2,163.09 |
| Egypt | 731,814 | 1,484,358 | 3,162,166 | 2,385,204 | 2,636,468 | 3,024,161 | 2,693,851 | 5.52 | 368.11 |
| Chinese | 322,294 | 592,625 | 1,086,768 | 1,284,089 | 1,142,542 | 1,270,198 | 2,664,763 | 5.46 | 826.81 |
| Italy | 1,032,228 | 1,450,661 | 2,177,101 | 1,846,050 | 1,822,808 | 1,827,408 | 2,039,111 | 4.18 | 197.54 |
| Algeria | 824,374 | 1,140,898 | 2,053,268 | 1,993,165 | 2,071,961 | 1,636,591 | 1,828,931 | 3.75 | 221.86 |
| Brazil | 910,566 | 1,057,830 | 1,763,886 | 1,233,720 | 1,502,383 | 1,491,220 | 1,459,354 | 2.99 | 160.27 |
| Philippines | 435,066 | 451,822 | 792,721 | 1,108,797 | 1,682,640 | 1,847,093 | 1,573,208 | 3.22 | 361.60 |
| Bangladesh | 205,403 | 342,841 | 861,499 | 1,138,229 | 1,115,434 | 1,098,284 | 1,439,760 | 2.95 | 700.94 |
| Nigeria | 262,876 | 705,638 | 1,334,933 | 1,179,342 | 1,198,237 | 1,151,759 | 1,483,996 | 3.04 | 564.52 |
| Others | 11,390,350 | 17,498,256 | 30,876,145 | 26,930,857 | 27,927,568 | 25,870,509 | 28,672,962 | 58.75 | 251.73 |
| Total | 16,731,872 | 25,873,091 | 47,200,560 | 42,818,753 | 44,960,379 | 44,318,709 | 48,806,483 | 100.00 | 291.70 |

Source: [13].

World wheat flour export quantity and value were 8.71 million tons and 1.78 billion dollars in 2000-02 average. In 2020, the quantity of exports increased by 57.02 percent to 13.67 million tons, and the export value increased by 189.50% to 5.17 billion dollars. Türkiye, Kazakhstan, Germany, Uzbekistan, Argentina, and Türkiye were the top exporters of wheat flour, accounting for 22.45%, 12.79%, 6.73%, 5.39%, and 4.50% of global exports, respectively (Table 4).

Compared to the average of 2000-02, the highest increase in 2020 occurred in Uzbekistan.

The reason for this is the expansion of the wheat production area in Uzbekistan after 1991 and the agricultural reforms made in the last 22 years [23]. Türkiye's export share in world wheat flour is very important. In 2020, Türkiye's wheat flour export amounted to 983 million dollars, with a share of 19.04% of world wheat flour exports. Compared to the average of 2002-2002 years, Türkiye increased its wheat flour export quantity by 11.63 times and wheat flour export value by 19.87 times in 2020 (Table 4).

Türkiye is the leading country in wheat flour in terms of export quantity and value. In the Grain Sector Report of the Turkish Grain Board for 2019, it was stated that 640 wheat flour factories operate in Türkiye and the capacity utilization rate of these factories was 51% [35]. Türkiye's leadership in the world wheat flour sector depends on wheat imports, not depends on local dynamics [26].

This may be because wheat flour exports remained below wheat imports during the period. Türkiye's wheat flour export was 1.1 billion dollars in 2021. The main countries where wheat flour was exported were Iraq (43.37%), Yemen (9.64%), Syria (9.17%), Djibouti (5.86%), Angola (5.15%) and Venezuela (4.25%) (Figure 1). These countries constituted 77.45% of Türkiye's total wheat flour export.

Table 4. Export quantities and values of leading wheat flour exporting countries

| Countries | 2000-2002 | 2005-2007 | 2010-2012 | 2015-2017 | 2018 | 2019 | 2020 | Percent (2020) % | Index (2002-02 = 100) |
|---|---|---|---|---|---|---|---|---|---|
| | **Export Quantity (Thousand tons)** | | | | | | | | |
| Türkiye | 264 | 1,505 | 2,004 | 3,320 | 3,400 | 3,344 | 3,070 | 22.45 | 1,162.88 |
| Kazakhistan | 256 | 1,170 | 2,148 | 2,180 | 2,307 | 1,569 | 1,749 | 12.79 | 683.20 |
| Germany | 660 | 537 | 681 | 891 | 937 | 958 | 920 | 6.73 | 139.39 |
| Uzbekistan | 1 | 3 | 2 | 202 | 309 | 419 | 737 | 5.39 | 73,700.00 |
| Argentina | 314 | 357 | 895 | 587 | 600 | 660 | 615 | 4.50 | 195.86 |
| Egypt | 7 | 16 | 82 | 217 | 427 | 680 | 394 | 2.88 | 5,628.57 |
| Belgium | 813 | 715 | 585 | 508 | 412 | 326 | 357 | 2.61 | 43.91 |
| Italy | 658 | 420 | 161 | 270 | 331 | 312 | 335 | 2.45 | 50.91 |
| USA | 640 | 244 | 317 | 329 | 284 | 285 | 281 | 2.06 | 43.91 |
| India | 387 | 38 | 105 | 225 | 191 | 206 | 262 | 1.92 | 67.70 |
| Others | 4,706 | 5,104 | 5,658 | 6,132 | 6,099 | 6,143 | 4,951 | 36.21 | 105.21 |
| Total | 8,707 | 10,110 | 12,635 | 14,859 | 15,296 | 14,901 | 13,672 | 100.00 | 157.02 |
| | **Export Value (Thousand dollars)** | | | | | | | | |
| Türkiye | 49,489 | 325,738 | 808,469 | 1,057,957 | 1,039,914 | 1,082,657 | 983,498 | 19.04 | 1,987.31 |
| Kazakhistan | 33,949 | 217,980 | 564,709 | 490,031 | 450,425 | 363,878 | 491,852 | 9.52 | 1,448.80 |
| Germany | 136,989 | 170,499 | 290,881 | 316,695 | 360,167 | 361,402 | 359,408 | 6.96 | 262.36 |
| Uzbekistan | 135 | 546 | 500 | 44,798 | 70,085 | 104,575 | 218,609 | 4.23 | 161,932.59 |
| Argentina | 56,731 | 99,765 | 347,679 | 181,963 | 192,983 | 221,335 | 202,322 | 3.92 | 356.63 |
| Egypt | 1,993 | 4,755 | 35,746 | 90,096 | 164,911 | 225,963 | 141,831 | 2.75 | 7,116.46 |
| Belgium | 160,547 | 226,808 | 250,206 | 178,252 | 149,686 | 119,536 | 132,923 | 2.57 | 82.79 |
| Italy | 129,499 | 121,041 | 99,956 | 156,151 | 200,181 | 192,342 | 215,906 | 4.18 | 166.72 |
| USA | 135,736 | 83,433 | 155,964 | 160,647 | 142,438 | 147,906 | 154,325 | 2.99 | 113.69 |
| India | 46,718 | 12,320 | 43,152 | 102,441 | 107,980 | 111,534 | 146,310 | 2.83 | 313.18 |
| Others | 1,032,171 | 1,534,413 | 2,494,625 | 2,413,522 | 2,451,958 | 2,428,746 | 2,117,517 | 41.00 | 205.15 |
| Total | 1,783,957 | 2,797,298 | 5,091,888 | 5,192,552 | 5,330,728 | 5,359,874 | 5,164,501 | 100.00 | 289.50 |

Source: [13].

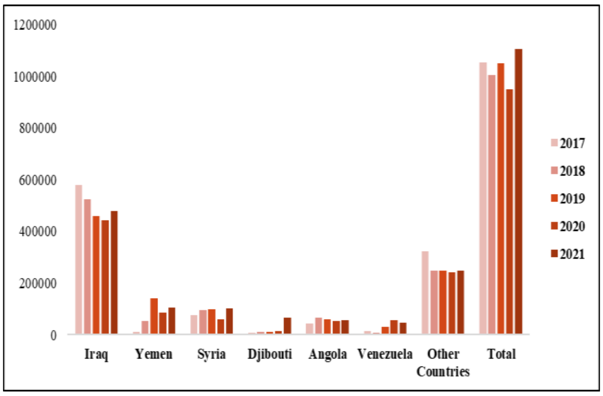


Fig. 1. Leading countries in Türkiye's wheat flour industry exports
Source: [18].

World wheat flour import quantity and value were 8.09 million tons and 1.75 billion dollars in 2000-02 average. In 2020, the quantity of imports increased by 68.41% to 13.63 million tons and the export value increased by 209.07% to 5.42 billion dollars. The leading countries in wheat flour import were Afghanistan with a share of 13.91%, Iraq with a share of 9.99%, the Netherlands with a share of 5.54%, China with a share of 3.13% and Yemen with a 2.80% share (Table 5). It was reported that the reason why Afghanistan ranks first in wheat flour imports is that 43% of the total household consumption expenditures in Afghanistan are spent on wheat-bread and grains and that imports are made intensively in order to meet the demand for these products [15]. Compared to the average of 2000-02, the highest increase in wheat flour import quantity and value was performed in Iraq in 2020. [2] stated that approximately 40% of daily food consumption in Iraq is wheat flour and its derivatives and if precautions are not taken, wheat productivity will decrease and dependence on imports will increase. Wheat flour import in Türkiye was scarcely any. In 2020, 0.10% of the world's wheat flour import quantity and 0.08% of the import value was made by Türkiye, ranking 108th in the world. Türkiye's wheat exports increased over the years, but wheat imports were higher in the same periods (Table 6). This is because Türkiye exports the wheat it imports after processing it into wheat flour. However, this foreign trade deficit is covered by the export of wheat flour. It was determined that Türkiye has self-sufficiency in wheat except for 2019.

Table 5. Import quantities and values of leading wheat flour importing countries

| Countries | 2000-2002 | 2005-2007 | 2010-2012 | 2015-2017 | 2018 | 2019 | 2020 | Percent (2020) % | Index (2002-02 = 100) |
|---|---|---|---|---|---|---|---|---|---|
| | Import Quantity (Thousand tons) | | | | | | | | |
| Afghanistan | 356 | 638 | 892 | 1,887 | 2,273 | 1,769 | 1,896 | 13.91 | 532.58 |
| Iraq | 10 | 900 | 885 | 1,582 | 1,660 | 1,382 | 1,362 | 9.99 | 13,620.00 |
| Holland | 259 | 316 | 511 | 537 | 732 | 725 | 755 | 5.54 | 291.51 |
| Chinese | 228 | 240 | 216 | 285 | 438 | 498 | 426 | 3.13 | 186.84 |
| Yemen | 372 | 46 | 30 | 192 | 126 | 325 | 382 | 2.80 | 102.69 |
| Bolivia | 129 | 171 | 210 | 264 | 276 | 311 | 364 | 2.67 | 282.17 |
| France | 272 | 212 | 259 | 357 | 337 | 342 | 358 | 2.63 | 131.62 |
| Uzbekistan | 75 | 539 | 1,110 | 691 | 648 | 455 | 353 | 2.59 | 470.67 |
| USA | 181 | 210 | 199 | 295 | 334 | 321 | 343 | 2.52 | 189.50 |
| Malaysia | 41 | 54 | 237 | 221 | 275 | 304 | 297 | 2.18 | 724.39 |
| Türkiye | 1 | 0.08 | 0.20 | 59 | 15 | 22 | 13 | 0.10 | 1,300.00 |
| Others | 6 ,171 | 6,912 | 7,892 | 7,865 | 8,043 | 7,749 | 7,082 | 51.96 | 114.76 |
| Total | 8,094 | 10,238 | 12,442 | 14,236 | 14,881 | 13,891 | 13,631 | 100.00 | 168.41 |
| | Import Value (Thousand dollars) | | | | | | | | |
| Afghanistan | 43,550 | 158,679 | 260,468 | 592,898 | 764,475 | 489,500 | 620,869 | 11.46 | 1,425.65 |
| Iraq | 1,883 | 184,918 | 419,490 | 603,838 | 605,870 | 522,314 | 506,690 | 9.35 | 26,908.66 |
| Holland | 52,616 | 101,781 | 191,216 | 181,782 | 250,742 | 227,589 | 244,262 | 4.51 | 464.24 |
| Chinese | 76,464 | 87,764 | 131,843 | 162,332 | 206,253 | 238,708 | 207,607 | 3.83 | 271.51 |
| Yemen | 55,467 | 7,924 | 11,839 | 74,858 | 41,321 | 126,828 | 130,845 | 2.41 | 235.90 |
| Bolivia | 29,248 | 42,366 | 80,109 | 88,554 | 97,805 | 116,053 | 127,777 | 2.36 | 436.87 |
| France | 60,934 | 83,495 | 129,991 | 155,944 | 158,849 | 163,856 | 179,172 | 3.31 | 294.04 |
| Uzbekistan | 14,731 | 111,573 | 313,629 | 151,966 | 109,030 | 87,270 | 89,701 | 1.66 | 608.93 |
| USA | 58,253 | 89,918 | 132,556 | 207,769 | 232,237 | 221,152 | 238,634 | 4.40 | 409.65 |
| Malaysia | 6,574 | 14,448 | 96,491 | 67,091 | 88,994 | 100,967 | 99,121 | 1.83 | 1,507.77 |
| Türkiye | 125 | 31 | 129 | 18,905 | 4,599 | 6,047 | 4,095 | 0.08 | 3,276.00 |
| Others | 1,353,265 | 2,100,043 | 3,491,729 | 3,159,129 | 3,096,010 | 3,026,215 | 2,969,507 | 54.81 | 219.43 |
| Total | 1,753,110 | 2,982,940 | 5,259,489 | 5,465,067 | 5,656,185 | 5,326,499 | 5,418,280 | 100.00 | 309.07 |

Source: [13].

Table 6. Türkiye wheat and wheat flour foreign trade balance

| Indicators | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| Wheat exports (thousand dollars) | 33,246 | 12,807 | 20,303 | 33,825 | 65,312 | 60,232 |
| Wheat imports (thousand dollars) | 1,111,453 | 1,079,760 | 1,275,251 | 1,477,326 | 2,556,404 | 2,468,086 |
| Balance | -1,078,207 | -1,066,953 | -1,254,948 | -1,443,501 | -2,491,092 | -2,407,854 |
| Wheat flour export (thousand dollars) | 999,480 | 1,259,806 | 1,251,358 | 1,198,580 | 1,178,626 | 1,082,325 |
| Wheat flour import (thousand dollars) | 1,601 | 22,386 | 35,092 | 4,831 | 7,352 | 4,385 |
| Balance | 997,879 | 1,237,420 | 1,216,266 | 1,193,749 | 1,171,274 | 1,077,940 |
| Self-sufficiency rate | 113.6 | 103.8 | 111.7 | 100.5 | 89.5 | 102.3 |

Source: [13] [37].

## Competitiveness analysis in wheat flour

According to the revealed comparative advantage index, it was determined that the comparative advantage of Kazakhstan, Türkiye, Uzbekistan, Egypt and Argentina in world wheat flour export was high. The mean RCA values of these countries were calculated as 28.79, 21.10, 16.53, 11.18 and 11.13, respectively. It was determined that Belgium, India and Italy had a weak comparative advantage, while Germany and the USA did not have a comparative advantage (Table 7). It was determined that Uzbekistan did not have a comparative advantage between 2010 and 2013 but that since 2014, it has had a high comparative advantage. This can be explained by the fact that Uzbekistan's wheat flour export value increased 88 times in 2014 compared to the previous year. In Türkiye, the RCA values of wheat flour exports varied between 18.99 and 24.17, and it was determined that it maintains its competitiveness over the years. In their study, [21] calculated the average RCA values in Türkiye's wheat export as 0.26 from 2001-2018 and 2.82 in the export of wheat products. They found no comparative advantage in wheat exports but a moderate comparative advantage in wheat products export. They indicated that Türkiye is in a strong position among wheat products, especially in the wheat flour and pasta sectors.

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Table 7. Revealed Comparative Advantage Index (RCA)

| RCA | Kazakhstan | Türkiye | Uzbekistan | Egypt | Argentina | Belgium | India | Italy | Germany | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 35.10 | 20.45 | 0.23 | 2.44 | 15.97 | 2.20 | 0.29 | 0.66 | 0.69 | 0.43 |
| 2011 | 19.86 | 21.97 | 0.23 | 5.09 | 15.22 | 1.73 | 0.35 | 0.66 | 0.66 | 0.35 |
| 2012 | 21.86 | 18.99 | 0.25 | 4.46 | 14.75 | 1.87 | 0.91 | 0.74 | 0.78 | 0.34 |
| 2013 | 22.28 | 19.54 | 0.19 | 4.21 | 3.10 | 1.84 | 1.43 | 0.86 | 0.87 | 0.31 |
| 2014 | 23.97 | 19.31 | 20.71 | 6.27 | 7.28 | 1.57 | 1.46 | 0.91 | 0.83 | 0.29 |
| 2015 | 33.30 | 21.56 | 21.27 | 13.26 | 8.14 | 1.52 | 1.45 | 1.00 | 0.73 | 0.33 |
| 2016 | 43.22 | 24.17 | 18.21 | 11.43 | 10.34 | 1.33 | 1.12 | 1.05 | 0.72 | 0.38 |
| 2017 | 32.79 | 23.10 | 15.52 | 11.88 | 11.88 | 1.34 | 1.04 | 1.11 | 0.78 | 0.32 |
| 2018 | 26.79 | 22.45 | 23.27 | 20.28 | 11.32 | 1.16 | 1.21 | 1.32 | 0.84 | 0.31 |
| 2019 | 22.04 | 20.93 | 25.49 | 25.79 | 11.88 | 0.94 | 1.21 | 1.25 | 0.85 | 0.31 |
| 2020 | 35.51 | 19.65 | 56.44 | 17.93 | 12.49 | 1.07 | 1.80 | 1.47 | 0.88 | 0.37 |
| Average | 28.79 | 21.10 | 16.53 | 11.18 | 11.13 | 1.51 | 1.11 | 1.00 | 0.78 | 0.34 |

Source: Own calculation.

According to the trade balance index, it was determined that Kazakhstan, Türkiye, Egypt, Argentina, India, Italy, Germany, and Belgium were net exporters in wheat flour foreign trade, while Uzbekistan and the USA were net importers. The average TBI values were calculated as 1.00 for Argentina, 0.99 for Kazakhstan, 0.99 for Türkiye, 0.96 for India, 0.86 for Egypt, 0.80 for Italy and 0.78 for Germany in the examined years (Table 8). It can be stated that these countries are strong in terms of export in wheat flour foreign trade.

In Türkiye, the TBI value was calculated as 1.00 between 2010-2015, 0.96 and 0.94 in 2016 and 2017, and 0.99 between 2018-2020 (Table 8).

Table 8. Trade Balance Index (TBI)

| TBI | Kazakhstan | Türkiye | Uzbekistan | Egypt | Argentina | Belgium | India | Italy | Germany | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| 2010 | 1.00 | 1.00 | -1.00 | 0.94 | 1.00 | 0.52 | 0.91 | 0.72 | 0.69 | 0.10 |
| 2011 | 0.98 | 1.00 | -1.00 | 0.91 | 1.00 | 0.43 | 0.95 | 0.79 | 0.66 | 0.06 |
| 2012 | 0.99 | 1.00 | -1.00 | 0.92 | 1.00 | 0.44 | 0.96 | 0.54 | 0.78 | 0.09 |
| 2013 | 0.99 | 1.00 | -1.00 | 0.82 | 1.00 | 0.43 | 0.97 | 0.70 | 0.87 | -0.02 |
| 2014 | 0.99 | 1.00 | -0.71 | 0.80 | 1.00 | 0.51 | 0.98 | 0.77 | 0.83 | -0.13 |
| 2015 | 0.99 | 1.00 | -0.67 | 0.80 | 1.00 | 0.51 | 0.98 | 0.85 | 0.73 | -0.14 |
| 2016 | 0.99 | 0.96 | -0.53 | 0.74 | 1.00 | 0.48 | 0.97 | 0.85 | 0.72 | -0.07 |
| 2017 | 0.99 | 0.94 | -0.33 | 0.83 | 1.00 | 0.49 | 0.97 | 0.89 | 0.78 | -0.18 |
| 2018 | 0.99 | 0.99 | -0.22 | 0.92 | 1.00 | 0.40 | 0.97 | 0.90 | 0.84 | -0.24 |
| 2019 | 0.98 | 0.99 | 0.09 | 0.92 | 1.00 | 0.37 | 0.96 | 0.94 | 0.85 | -0.20 |
| 2020 | 0.98 | 0.99 | 0.42 | 0.82 | 1.00 | 0.34 | 0.98 | 0.90 | 0.88 | -0.21 |
| Average | 0.99 | 0.99 | -0.54 | 0.86 | 1.00 | 0.45 | 0.96 | 0.80 | 0.78 | -0.09 |

Source: Own calculation.

## CONCLUSIONS

Wheat is a strategic product for countries in terms of its contribution to nutrition and the economy. Wheat flour obtained from wheat processing is important for Türkiye due to its export potential. Furthermore, since wheat is processed within the scope of DIR, it becomes an incentive element for businesses by bringing many advantages such as tax exemption, reduction of input costs and more efficient use of operating capacity. In the study, the international competitiveness of the wheat flour industry, in which Türkiye is the leader, is demonstrated by the Revealed Comparative Advantage Index (RCA) and the Trade Balance Index (TBI). The ranks of competitiveness of wheat flour exports in terms of RCA values were Kazakhstan, Türkiye, Uzbekistan, Egypt and Argentina. On the other hand, regarding TBI values, Kazakhstan, Türkiye, Egypt, Argentina, India, Italy, Germany and Belgium were net exporters, while Uzbekistan and the USA were net importers in foreign trade wheat flour. There is no problem in the production of raw materials in the Turkish wheat flour industry, but there is a problem in the supply of quality raw materials. For the producers to produce quality wheat, agricultural subsidies tools should be used effectively. For example, giving higher subsidies in wheat production to varieties with high protein content will direct the farmers to produce quality varieties. In this case, the quality raw materials demanded by the flour industry will be supplied from within the country and raw material imports will decrease.

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# LIFESPAN OF COWS OF DAIRY CATTLE DEPENDING ON THE UDDER LINEAR TRAITS EVALUATION

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***Abstract***

*The aim of the paper was to study the lifespan dependence of Ukrainian Red-and-White dairy (URWD) and Ukrainian Black-and-White dairy (UBWD) breeds on the level of linear traits evaluation that characterize the udder morphological qualities in the overall system of linear classification of the conformation type. The experiments were conducted in the herds of Cherkasy and Sumy regions for breeding URWD (n = 465) and UBWD (n = 598) breeds. By the trait fore udder parts attachment, reliable difference between cows, estimated at 1 and 9 scores, was 636 (URWD; P <0.001) and 721 (UBWD; P <0.001) days. The difference between the lowest and highest scores of the height of attachment of the udder rear parts in cows of experimental breeds was 663 (URWD; P <0.001) and 715 (UBWD; P <0.001) days. Animals with an assessment of the development of central udder ligament above 5-8 scores lived longer, according to assessed breeds, from 2,402 to 2,723 (URWD) and from 2,572 to 2,869 (UBWD) days. Cows of the UBWD breed estimated at 5-9 scores lived on 141-170 (P <0.01) days longer compared to the URWD cows. Relative variability between the udder depth and lifespan was curvilinear, as higher lifespan observed in cows with 6-7 scores. Cows of both breeds with an average grade of 7 for the fore teats position were used the longest in the herd. Evaluation of the relative variability of the fore teats length and cow's lifespan of controlled breeds showed that cows had a longer functional life with an average score of 5 and 6. The relative variability established between the evaluation of linear traits that characterize the udder morphological structure and the lifespan of cows testified about the effectiveness of animal selection by type in the direction of longevity. Linear traits that positively correlate with the lifespan of cows can be used in the future as indirect predictors of longevity.*

***Key words***: *Ukrainian Red-and-White dairy breed, Ukrainian Black-and-White breed, linear type traits, lifespan*

## INTRODUCTION

The use of the Holstein gene pool in the process of improving Ukrainian dairy breeds undoubtedly led to an increase in their milk productivity. However, cows with a high share inheritance of Holstein became more demanding on the conditions of feeding and keeping [24]. High mechanization of technological processes and growth of Holstein inheritance, by testimony of studies [23, 32], led to decrease in the indicators of the productive longevity of cows. Therefore, the lifelong productivity of cows, as the most important productive trait, was included in the selection indices developed in the individual countries [22, 30]. This was one of the main factors influencing the profitability of dairy cattle breeding. Due to its high economic value, the national dairy associations have registered longevity as a selection trait [21].

Since cattle breeders were interested in the traits that were inherited and the solution to the problem of longevity due to inheritance factors became more complicated precisely because of the low heritability of the traits that characterize it, especially those related to lifespan. Worldwide studies have confirmed this property [12, 14, 32, 34].

This population-genetic regularity was confirmed by summarizing a number of studies of brown Swiss, Guernsey, Holstein, Jersey, Red dairy and Simmental breeds from 19 countries of the world, by which the heritability of lifespan was quite low and ranged from 0.016-0.116 [8].

Problem of dairy cattle productive longevity in the world has existed for a long time, so breeders are actively searching for methods to decide it. One of the means to solve the problem of lifespan was animals' selection by the traits of conformation type. The motivation for this event was based on the existence of positive correlation between parts of the body structure of the conformation and indicators of cows' duration use [4, 13, 14, 33, 34].

According to the linear assessment of Jersey cows, were established significant moderate and strong positive genetic correlations between most of the udder traits and the functional life of cows in the herd (from 0.23 to 0.63) [7]. Authors [9] on studies of Mexican Holsteins proposed to include five linear traits (chest width, teats length, central ligament, texture and udder depth) that positively correlated with productive lifespan as indirect predictors of longevity.

Authors [15] were sure that indirect genetic selection for traits: udder depth, rear teats position and udder texture, bone quality, fore udder attachment, body depth, and chest width can lead to a correlated increase in Holstein cows' longevity.

The use of linear classification method in the selection process of improving Ukrainian dairy breeds made it possible to identify the desired development of those linear traits on which the animals' lifespan will depend, in order to consider them in the process of selection.

Therefore, the purpose of our research was to study the lifespan dependence of cows of the Ukrainian Red-and-White dairy (URWD) and Ukrainian Black-and-White dairy (UBWD) breeds on the level of linear traits assessment that characterize morphological qualities of the udder in the overall system of linear classification of the conformation type.

## MATERIALS AND METHODS

The research base was the leading selection herds of the Cherkasy and Sumy regions for breeding Ukrainian Red-and-White (n=465) and Black-and-White (n=598) dairy breeds. The conformation type of first-born cows was assessed using the linear classification method according to the latest ICAR recommendations [11] at the age of 2-4 months after calving. The lifespan of cows was determined by the number of days between the dates of birth and date of withdrawal from the herd. Experimental indicators using methods of biometric statistics, calculated according to the formulas of E. K. Merkurieva [20].

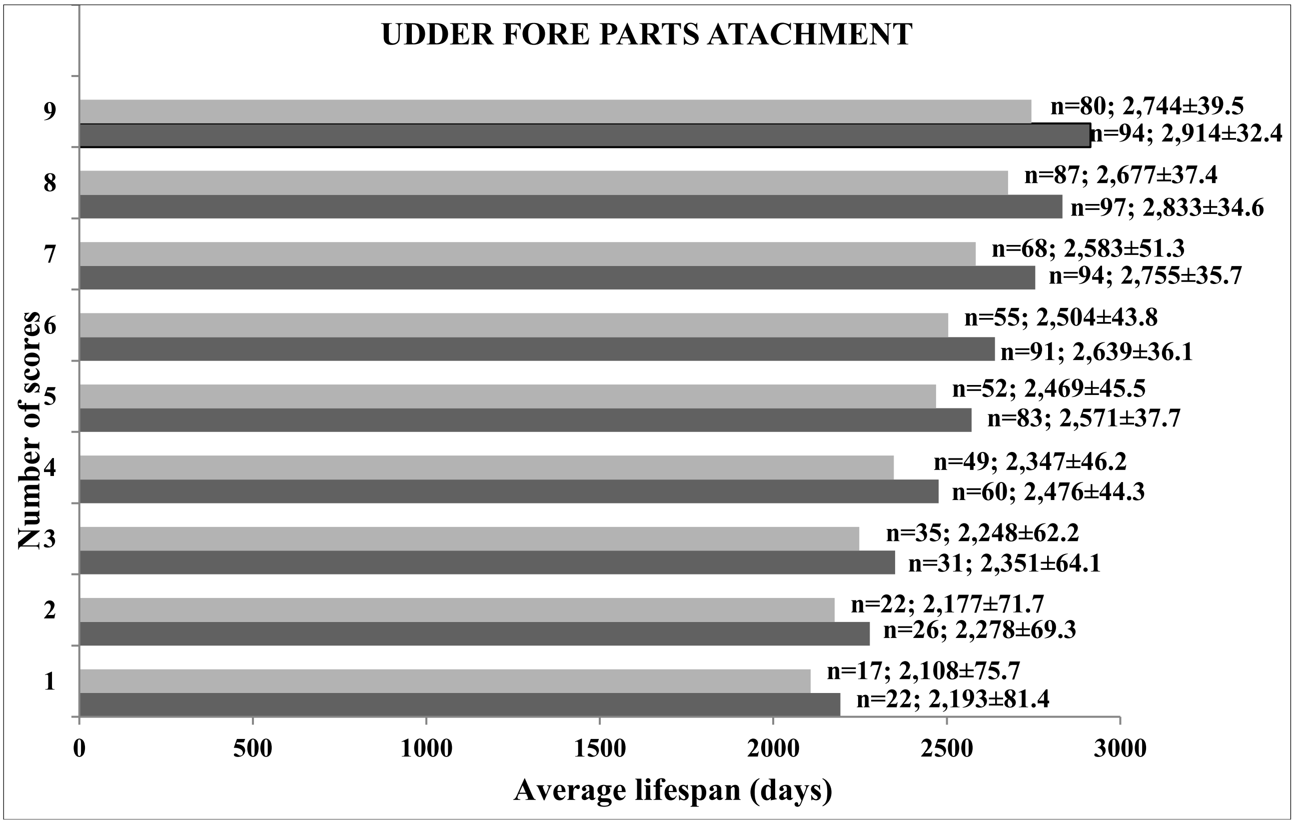
## RESULTS AND DISCUSSIONS

Milk yield is closely linked to conformation traits among which udder traits occupy a special place from a genetic point of view, a a reason to be used in cows' selection and breeding [18, 19].

The evaluation of udder morphological traits of dairy cows in the linear classification system occupied a certain place, because in the final score of type its share in the most countries was 40% [1]. Scientific and practical experience in the selection of dairy cattle has repeatedly confirmed that the udder morphological traits are the most important and reliable external indicators of high milking capacity [3] and manufacturability of cows [8]. Linear classification of the body type descriptive traits was carried out, characterizing such morphological udder qualities of first-born cows as: fore udder parts attachment, height of the udder rear parts attachment, central ligament, udder depth, fore teats position and length. A certain relative variability was established between the assessment level of these type traits and the production and lifespan of animals [28, 29].

The udder fore parts attachment to the cow's belly, as one of the most important descriptive traits, assessed by strength, characterizing by an angle formed at this junction. The highest grade (9 score) for this body part development was received by an animal in which the udder differed by gradual transition glandular tissue of the fore part into the belly with help of connective lateral ligaments with formation of an obtuse angle above 161° [22]. The strength of udder attachment characterized by excellent fore parts development and the bath-like form. The functional feature of the attachment strength of the udder fore parts was prevention it from sagging with age, which ensured the effectiveness of longevity traits [2, 31].

Results of the trait assessment of the fore udder parts attachment (Fig. 1) showed the relative relationship presence between this trait development and cow's lifespan of evaluated breeds. Reliable difference between cows estimated at 1 and 9 scores was quite significant and amounted to 636 (URWD; P<0.001) and 721 (UBWD; P<0.001) days. An interbreed comparison the lifespan of cows depending on the evaluation was in favor of UBWD cows with variability ranging from 85-172 days with reliable difference when comparing estimates of 9 score (P<0.001). About significant influence this trait on the lifespan of cows was reported in the studies of foreign authors. Thus, when assessing cows of Jersey breed the highest relationship established between the fore udder parts attachment and functional life with genetic correlations for the first three lactations of 0.23; 0.63 and 0.33 [7], respectively. According to the genetic parameters evaluation of the Italian brown Swiss dairy cattle [25], the strong positive genetic correlation was determined between the fore udder parts attachment and milk yield (0.45), but insignificant - with the functional longevity (0.10).




*Note*: hereinafter - ■ - Ukrainian Red-and-White dairy breed; ■ - Ukrainian Black-and-White dairy breed.

Fig. 1. Relative variability in the evaluation of descriptive type trait "udder fore parts attachment" and cow's lifespan of controlled breeds

Source: Own results.

The next linear trait - height of the udder rear parts attachment, similarly to the previous one, performs a supporting function, not allowing the udder to sag with age. Desirable development of this body part was rated with the highest score. The difference between the lowest and highest scores for this trait, obtained from the results of studies in cows of tested breeds, was 663 (URWD; P<0.001) and 715 (UBWD; P<0.001) days (Fig. 2). Reliable advantage cows of the UBWD on this trait at 174–192 (P<0.001) days was established only by grades of 7–9 scores. Other studies had also reported about positive influence of this trait on the lifespan [2, 7, 29].

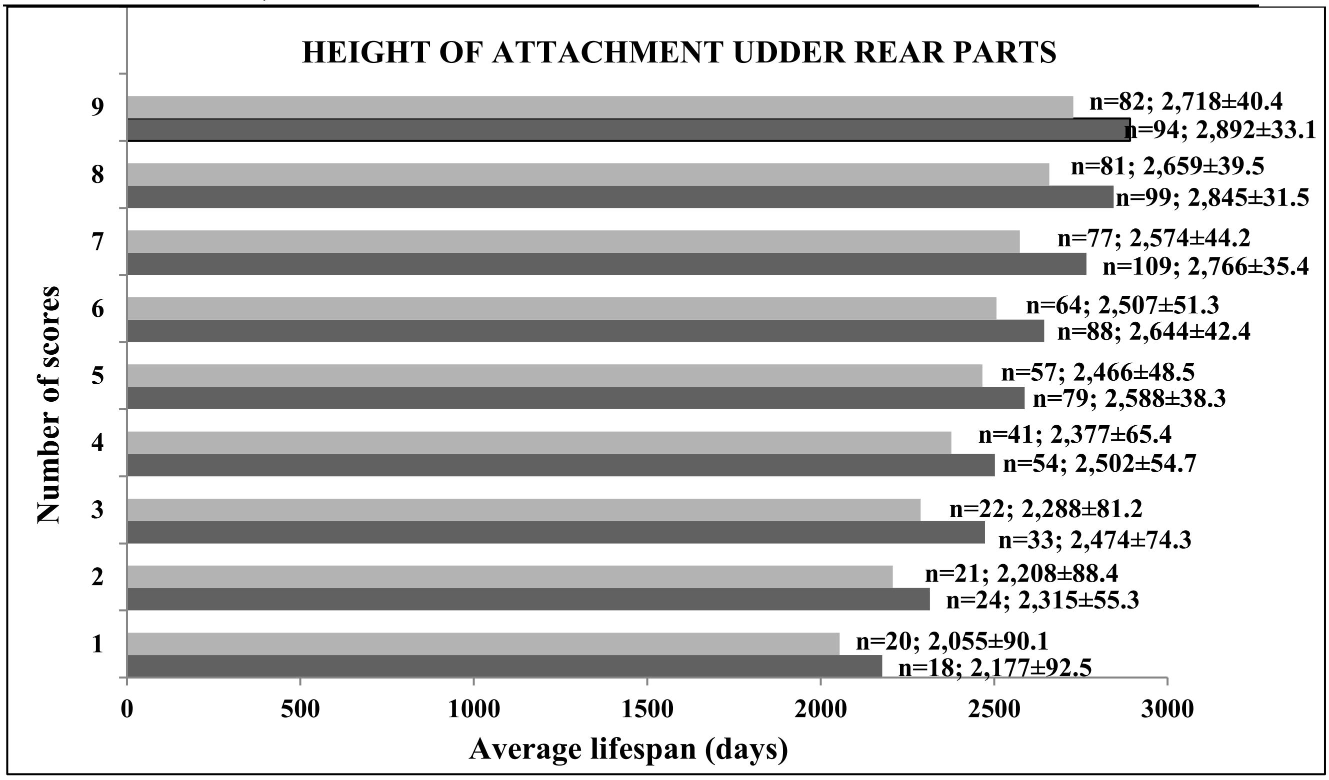



Fig. 2. Relative variability in the evaluation of descriptive type trait "height of attachment udder rear parts" and cow's lifespan of controlled breeds
Source: Own results.

The next linear udder trait in dairy cattle was the central ligament, related to its support at the appropriate height. The results of the experiment are shown in Fig. 3.

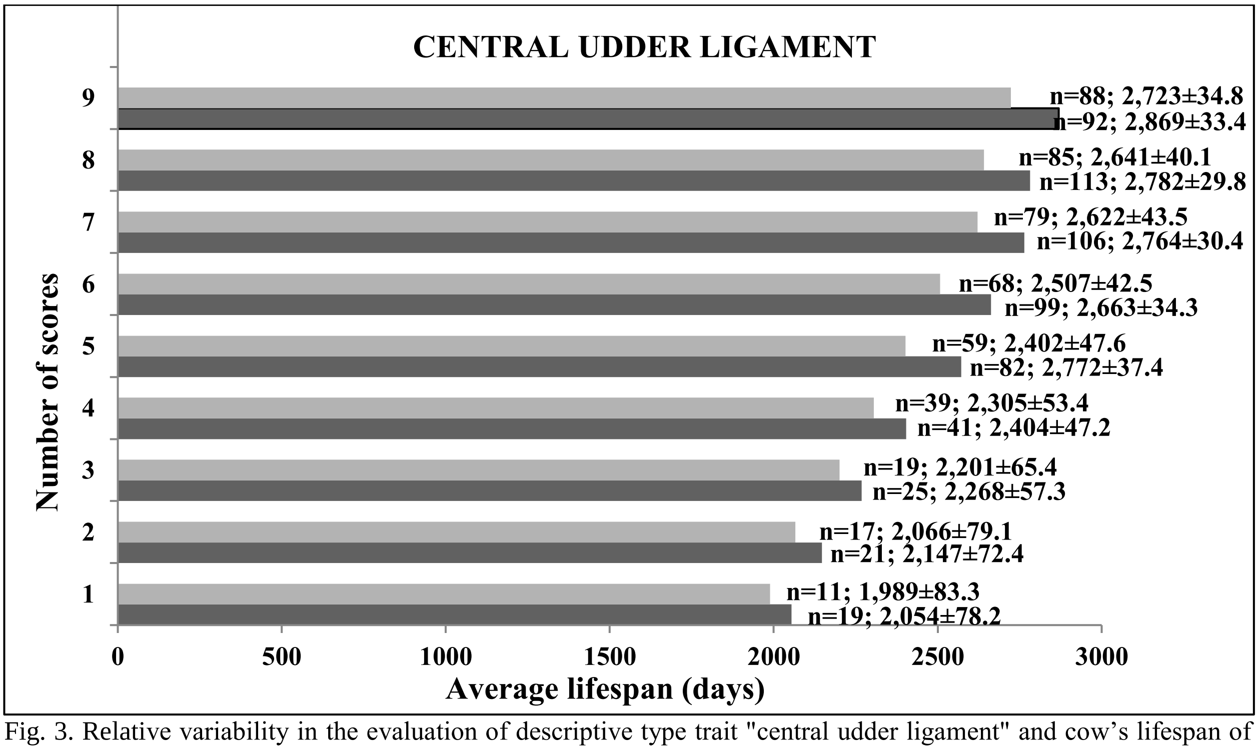



Fig. 3. Relative variability in the evaluation of descriptive type trait "central udder ligament" and cow's lifespan of controlled breeds
Source: Own results.

Highly located udder above the floor facilitated the operator to prepare it for milking process and during lying prevented cooling and injury. The high udder position with a deep, strength, well-defined and high raised central ligament was the desired trait development with the highest of 9 score.

Histogram's sleepers (Fig. 3) showed that the average cows' lifespan of tested breeds significantly depended on the score level for type trait central ligament. Animals with an assessment for the udder central ligament development above 5–8 scores lived longer, according to assessed breeds, from 2,402 to 2,723 (URWD) and from 2,572 to 2,869 (UBWD) days. Cows of the UBWD breed graded at of 5–9 scores lived longer by 141–170 (P<0.01) days compared to URWD cows. Accordingly, in agreement with our results, Schneider et al. [26] and Sewalem et al. [27] found that the supporting ligament of Holstein cows was one of the most important udder traits, as animals with lower scores (with extremely weak ligaments) were nearly twice as likely to be culled than animals with higher scores. The udder bottom location relative to the floor is a very important functional technological linear type trait of dairy cattle. The udder bottom distance to the floor significantly dependent on the previous three traits responsible for the strength of its attachment. Histogram indicators (Fig. 4) testified that cows with high udder position were significantly less susceptible to these risks and used in the herd over a much longer period of time.

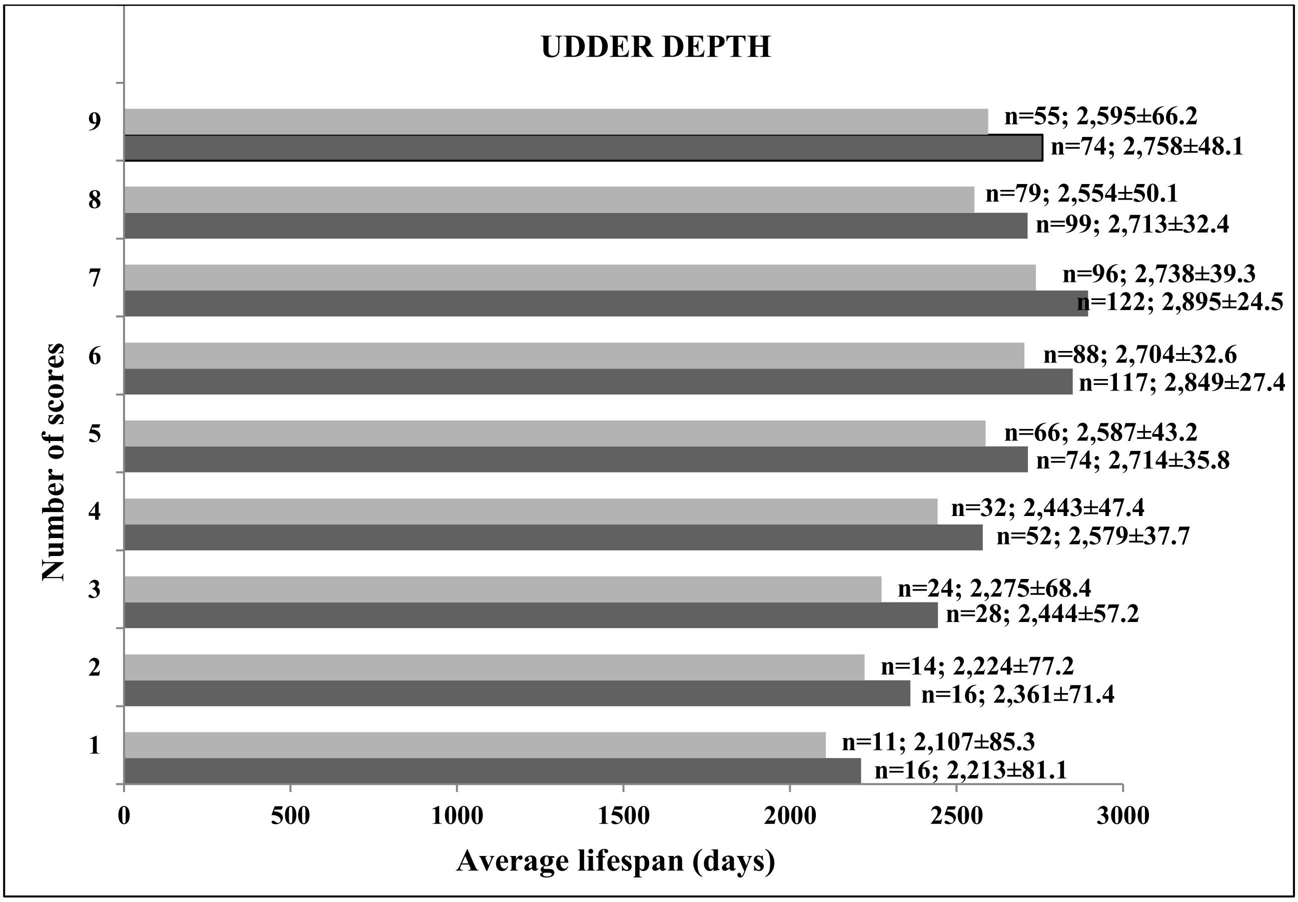



Fig. 4. Relative variability in the evaluation of descriptive type trait "udder depth" and cow's lifespan of controlled breeds
Source: Own results.

The relative variability between the udder depth and lifespan was curvilinear, as higher longevity observed in cows with 6–7 scores. A reliable decrease in the lifespan of cows will start from 4 to 1 scores. The significant decrease in the lifespan of cows began from assessment of 4 to 1 scores. The difference between the highest lifespan of cows with an assessment of 7 score and of 5–1 scores for udder depth was 151 – 631 days for cows of the URWD breed with reliable difference (P<0.01–0.001), and for UBWD cows was 181–682 days (P<0.001). An interbreed comparison showed the advantage cows of the UBWD breed over URWD by lifespan within all values of scores and for some the difference in their favor was reliable. Relative close relation of the udder depth and functional longevity was found in Italian brown Swiss cattle with genetic correlations of 0.42 ± 0.10 [25], South African Jerseys with correlations of 0.10–0.49 depending on lactation [7], that confirmed results of our research.

Another linear trait of the udder - the fore teats position, that is very important both from the selection and from technological point of view (Fig. 5). In general, the teats placement on the udder can be wide, almost square; wide fore and close rear teats; close lateral at normal distance between teats of the left and right sides; close placement of all teats. Both very close (up to 6 cm) and very long (more than 20 cm) distance between the teats tops was undesirable. Teats spaced at an optimal distance (12-16 cm), centrally located on the udder parts, vertically directed downwards, cylindrical or conical in shape, best met of machine milking requirements [17].

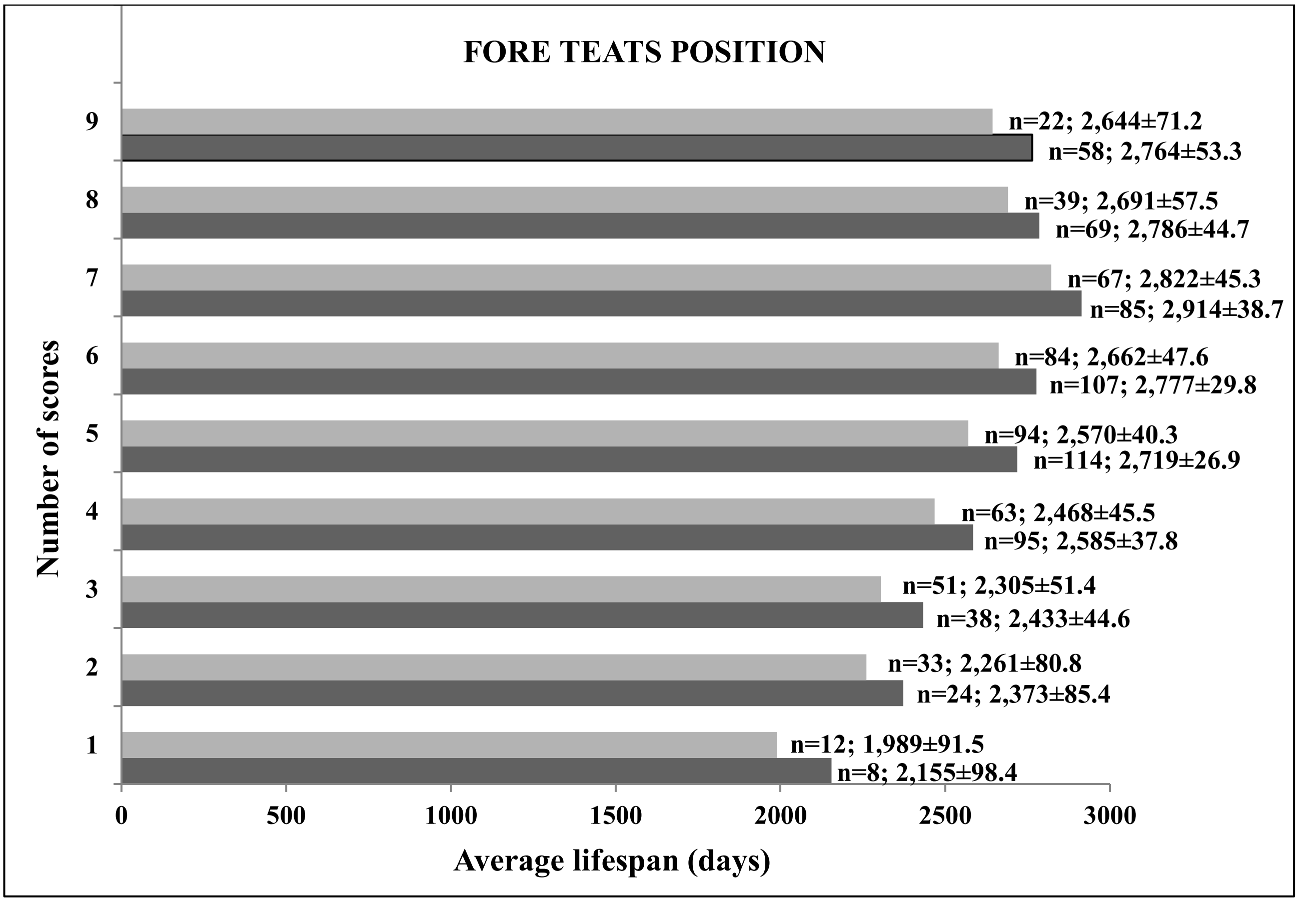



Fig. 5. Relative variability in the evaluation of descriptive type trait "fore teats position" and cow's lifespan of controlled breeds
Source: Own research.

Very close or very wide the fore and rear teats position is not the best trait development in the linear classification system. However, if you choose from extreme variants – the best was wider position than a narrow one. Histogram results showed that the cows lifespan of both breeds, depending on the assessment of fore teats position characterized by slight curvilinear variability. Cows of both breeds with an average score of 7 were used for the longest time in a herd. Further deviations towards decrease in the lifespan were observed in cows graded at 8-9 and 6-1 scores with advantage of the UBWD breed. The significant decrease in the lifespan indicator began in cows assessed for this trait from 4 to 1 scores, with an increase in the distance between the teats position. About positive influence of the fore teats placement on the functional longevity of cows of dairy breeds reported by other studies [5, 6, 7, 26, and 31].

The last of the udder linear traits – the teats length, refers more to the technological traits. Modern dairy cattle of different breeds are characterized by various indicators of the fore and rear teats length. According to studies [27], the teats length in first-born cows of Ukrainian Black-and-White dairy breed was 5.6 cm, and the Holstein breed – 5.8 cm. By researches data [3] of udder measurements of Holstein cows, it was found that the fore teats length was 5.37 cm, and the rear ones - 4.83 cm. According to recent studies of cows first-born Holstein cattle [10], the fore and rear teats length was 5.11 and 4.79 cm, respectively. Based on the experimental data of linear evaluation and correlation relationships between them and milk yield, the desired manifestation of the conformation type of first-born cows created of Ukrainian RWD and BWD breeds was established in the overall unity of the main descriptive type traits that are part of the linear classification system, by which the fore teats length should be 5 cm with 5 score [16, 17]. Analyzing the indicators of studies of cows of Ukrainian dairy breeds, it can be concluded that the fore and rear teats length corresponded to the desired type, varying within 5–6 cm, respectively to 5 and 6 scores of linear evaluation (Fig. 6).

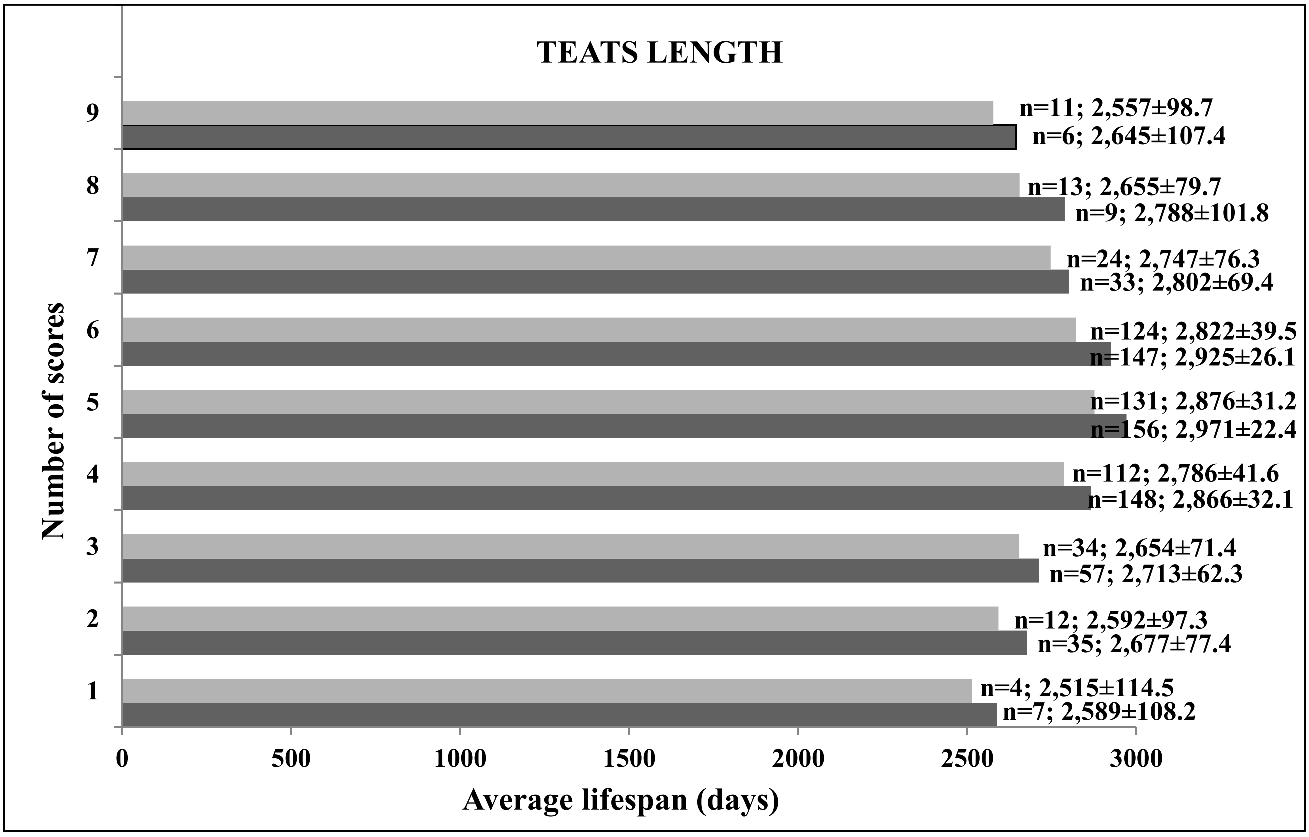



Fig. 6. Relative variability in the evaluation of descriptive type trait "teats length" and cow’s lifespan of controlled breeds
Source: Own results.

Evaluation of the relative variability of the fore teats length with cow’s lifespan of controlled breeds indicated that the functional life was longer in cows with average grade of 5 and 6. An increase in the assessment of this trait to 7–9 scores in cows of the URWD breed affected lifespan downward from 129 to 299 days, and decrease in the assessment to

3–1 scores from 222 to 361 (P<0.01). A similar comparison cows of the UBWD breed estimated at 5 and 6 scores with groups of animals graded at 7–9 showed a reduction in their lifespan by 123–326 days (P<0.01), and in cows with scores of 4-1, the life was reduced by 59-382 days.

Summarizing the results of the research, it was important to note that each of the evaluated descriptive traits in cows of both breeds had an influence on the lifespan with different variability within each specific type trait.

## CONCLUSIONS

The relative variability established between the evaluation of linear traits characterizing the udder morphological structure and the lifespan of cows testified about the effectiveness of animal selection by type in the direction of longevity. Linear traits positively correlated with cow lifespan can be used as indirect predictors of longevity.

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# DEVELOPMENT OF NON-AGRICULTURAL ENTREPRENEURSHIP IN RURAL AREAS OF THE FOOTHILLS AND MOUNTAINOUS PART OF THE UKRAINIAN CARPATHIANS

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***Abstract***

*The article examines the features of non-agricultural development in rural areas based on the research materials on rural entrepreneurship in the foothills and mountainous areas of the Ukrainian Carpathians, in particular in Lviv region. The methodological basis of the research consists of comparison, analogies, analysis and synthesis methods, process and system approaches etc. During the research the entrepreneurs' sociological survey was conducted. As a result of the research a range of problems that inhibit the effective development of mountainous and foothills areas and the factors that complicate the formation and effective use of the entrepreneurship intellectual and personnel potential in the specified region are identified. The directions of non-agricultural entrepreneurship diversification are determined (namely tourist, accommodation, recreational, trade, transport and other services as well as folk crafts), and the expediency and advantages of the rural tourism development on the territory of the Ukrainian Carpathians and the foothills are substantiated. The motivational aspects of entrepreneurial activity in the rural tourism field are considered. It can be concluded that non-agricultural activity is one of the most important elements of rural residents' alternative incomes and the intensification of economic activity in rural areas (in particular, foothills and mountainous).*

***Key words*****:** *entrepreneurship, non-agricultural entrepreneurship, rural tourism, the Carpathians*

## INTRODUCTION

Entrepreneurship should be considered a multifaceted phenomenon, which is determined by social, economic and cultural factors. In the social sphere, entrepreneurship is considered through the individual characteristics of a person (talent, intelligence, the ability to learn and use acquired knowledge, to make risky decisions), in the economic and cultural sphere, it is perceived through the quality of labor resources and the organizational culture of the enterprise (creativity, innovation, market orientation, making a profit, behavior, rules of ethics and etiquette).
In the foothills and mountainous territories, in addition to the mentioned factors, favorable prerequisites for the development of entrepreneurial potential are also needed, namely: the availability of resources (human, land, natural, ecological, touristic, recreational), the efficiency of their transformation ensures the possibility of socio-economic development of the territory, the improvement of the quality of life of the local population.

## MATERIALS AND METHODS

The works of scientists and practitioners dedicated to the entrepreneurial development of rural areas are a theoretical and methodological basis of the research, namely: Boyko V. [2], Golian S. [3], Grzybek B. [4], Hartman T. [5], Hubeni Yu. [6], Malik M. [8], Skyba T. [10], Trutenko H. [11], Vazhynskyi F., Kolodiychuk A. [12] and the others. The identified researchers determined the impact of entrepreneurship on the development of rural areas, the factors of development of rural entrepreneurship, and the organization of information support for the development of entrepreneurial activity in rural areas is investigated. At the same time, among scientific studies, there are not enough sources devoted to the problematic aspects of entrepreneurship development, taking into account the specifics of mountainous and foothills areas, including the Ukrainian Carpathian region.

The methodological basis of the research consists of comparison, analogies, analysis and synthesis methods; normative and positive approaches to the study of economic processes; process and system approaches. The information base of the research is statistical information from the State Statistics Committee of Ukraine and the calculations of the Department of Economic Policy of Lviv Regional State Administration. During the research, a sociological survey of the entrepreneurs operating in the districts was conducted. The survey was carried out in September-October 2019, that is, before the COVID-19 pandemic. The 98 entrepreneurs from the village of Slavsko and the town of Skole were polled, who provide accommodation, transport, and trade services, and who are registered as individual entrepreneurs, which is more than 2% of the total number of employees in the sector of small and medium entrepreneurship of the analyzed districts.

## RESULTS AND DISCUSSIONS

An important factor in the development of entrepreneurship is the legal framework. Entrepreneurial activity in Ukraine is regulated by various normative legal acts, in particular in the article of the Constitution of Ukraine. At the same time, the formed regulatory and legal framework for the development of entrepreneurship remains imperfect and contains many contradictions and the possibility of an adverse administrative influence on newly created entities, which negatively affects the availability of financial resources, information support, markets for products and means of their production, and professional training etc [8].

The informational factor influencing business activity is of key importance under the conditions of a rapid change in the external environment because the information is not only a prerequisite but also an important resource that determines production factors and the direction of all social development. From the point of view of information provision, the specificity of rural entrepreneurship lies in the fact that state institutions are not able to carry out explanatory work in every village, and every community on the measures to implement state policy in the field of entrepreneurship, regulatory and legal acts, state programs to support rural development.

The financial and credit component of the formation of the market type of management must be considered in the combination with other factors of ensuring rural entrepreneurship. Currently, the situation with access to loans does not differ from the other sectors of the Ukrainian economy. Rural entrepreneurs work hard but are deprived of access to cheap credit resources that would allow them to create a reliable material base and develop at higher rates. One of the main problems of entrepreneurial activity in the field of lending is the limited credit resources of credit institutions, which can be provided to borrowers against property or working capital. Entrepreneurial activity, in particular in the countryside, is quite capital-intensive, and therefore unable to function normally and develop without external assistance (banks, credit unions, and other credit institutions). These additional financial resources, obtained with the help of short-term loans, are necessary for conducting the operational activity and making current payments. The real state of affairs proves that the possibilities of lending to rural entrepreneurs are quite limited because the programs of lending to rural populations including “individual lending” and “household lending” developed by credit unions are rare and not easily accessible [10]. The provision of credit funds by banking institutions is carried out without taking into account the specifics and features of entrepreneurial activity in the foothills and mountainous territories, that is, on general terms.

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**Characteristics of entrepreneurial activity within the mountainous and foothills territories of Lviv region**

The mountainous and foothills territories of Lviv region, which are the subject of the study, include selected territorial united communities of three newly created administrative districts − Sambir, Stryi, and Drohobych. In general, the mountainous territories of the united territorial communities cover 17% of the area of Lviv region, 216 settlements are located there (about 12% of their total number in the region), but only 6.1% of the region's population live there. This is due to the peculiarities of the relief, specific climatic conditions, and partly the historical factors of the settlement of territories.

Studying the level of entrepreneurship in this type of territory, Polish scientists note that it has its specificity, which arises primarily from limited opportunities for the development of agriculture, and historical conditions associated with emigration, and a high level of self-employment, including well-developed regional folk crafts [4].

The studied territory has certain demographic features. The highest birth rate is noted in the mountainous united communities; as a result, the mountainous areas have a different age structure of the population: having only 6% of the population, 8% of the children of Lviv region live here.

The issue of demographic burden and imperfect structure of employment in mountainous areas remains relevant. The greatest demographic load is in Stryi and Drohobych districts, 30-40% of the entire labor market is unregistered, which is a significant resource for opening new enterprises and production facilities.

The sectoral structure of the economy of mountainous and foothills areas is characterized by a large share of agriculture and other services, which include education, health care, tourism, public administration, social services, etc. Instead, the share of the industry does not even reach 5%, construction − about 1% (Fig. 1).

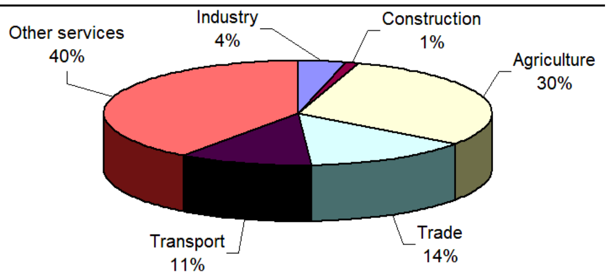


Fig. 1. Structure of the economy of mountainous areas
Source: the calculations of the Department of Economic Policy of Lviv Regional State Administration.

Transformational processes at the end of the 20th century led to the decline of industry in the region, which was mainly based on wood processing and the manufacture of various products from this raw material, and agriculture. Such a change in the structure of the economy of the studied territory over the past 30 years has caused rapid development of the service sector, including tourism and recreation.

A significant idle resource for the development of the mountainous areas of the region is the strengthening of the population's business activity, increasing the scale and efficiency of small and medium-sized business entities as a source of creating new jobs, increasing the level of employment of residents and increasing their well-being, improving the investment attractiveness of the territories, increasing revenues to local budgets, the development of social initiatives, the formation of a middle class and the development of social and economic infrastructure (Table 1).

Table 1. Comparative characteristics of the indicators of the development of small and medium entrepreneurship in Lviv region, its mountainous and other areas

| Territories | Indicators | | | | | |
|---|---|---|---|---|---|---|
| | Number of small and medium enterprises per 10,000 population | | | Number of employees at 1 small enterprise | Volumes of sold products per 1 employee at small enterprises, million UAH | Volumes of sold products per 1 small enterprise, million UAH |
| | small | medium | total | | | |
| Lviv region | 3.2 | 70.9 | 74.1 | 5.4 | 0.47 | 2.5 |
| Mountain communities | 0.9 | 23.2 | 24.1 | 4.7 | 0.38 | 1.8 |
| Other areas of the region | 2.1 | 46.5 | 48.6 | 5.6 | 0.54 | 2.9 |

Source: [7].

The indicators of entrepreneurial activity in the studied territory are characterized by negative aspects, which can be attributed to:

- significant impact of external factors on the activity of small and medium-sized enterprises, especially inflation, the low purchasing power of the population, access to sales markets, the epidemic of COVID-19, the war with Russia;
- decrease in the number of business entities in the small and medium business sector;
- low business activity and a small number of small and medium-sized enterprises per 10,000 people of the existing population, limited entrepreneurial initiatives among rural residents;
- decrease in the number of employees in the sector of small and medium entrepreneurship;
- small volumes and low efficiency of the financial and economic activity of representatives of small and medium-sized businesses, the limitation of their intellectual and personnel, material, technical, and resource support;
- limited number of practices for the formation of integrated trade and production systems and cooperative relations with the participation of small and medium entrepreneurship entities;
- low level of the development and efficiency of functioning of the entities of institutional support, the lack of proper road and transport connections, and a sufficient number of market, financial, social, and informational infrastructure objects;
- problems of formation, development, and reproduction of human capital.

The deterioration of socio-economic development of the mountainous regions of Lviv region harms the development of entrepreneurship, which pushes the local population, primarily young people, to labor migration abroad and to large cities, where the level of wages is much higher, the labor market is more saturated, the infrastructure is developed, and living conditions are better. This complicates the formation and effective use of the intellectual and personnel potential of small and medium entrepreneurship in mountainous regions. As a result of the decrease in the number of young people, the problem of “aging” and “extinction” of villages is actualized, which negatively affects the self-organization of the population and the implementation of business projects and public initiatives aimed at solving the current economic, household, and cultural problems of mountainous areas.

To identify the causes of the main problems, as well as key obstacles and promising directions and means of promoting the development of small and medium business in the foothills and mountainous areas of Lviv region, a sociological survey of the entrepreneurs operating in the regions was conducted. The survey was carried out in September-October 2019, that is, before the COVID-19 pandemic. The 98 entrepreneurs from the village of Slavsko and the town of Skole were polled, who provide accommodation, transport, and trade services, and who are registered as individual entrepreneurs, who represent more than 2% of the total number of employees in the sector of small and medium entrepreneurship of the analyzed districts. It is established that the main (the most problematic aspects of the functioning and development of small and medium-sized business entities according to the ranking results) causes of these problems are as follows (Fig. 2):

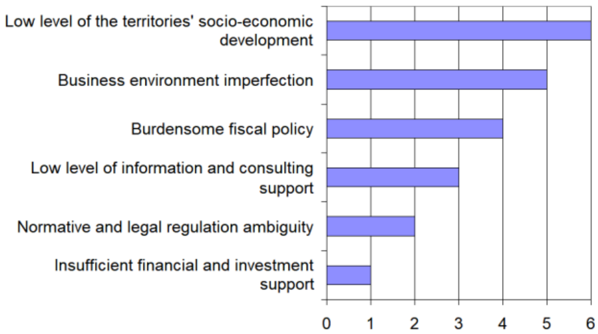


Fig. 2. Ranking of the problematic aspects of entrepreneurship development in the studied territory in 2019
Source: the results of surveys of Slavsko and Skole entrepreneurs in September-October 2019.

The obtained results proved that insufficient financial and investment support was identified by the respondents as the most significant problem of entrepreneurship development. In detailing this problem, several factors that significantly inhibit the processes of entrepreneurial activity were revealed, namely (Fig. 3):

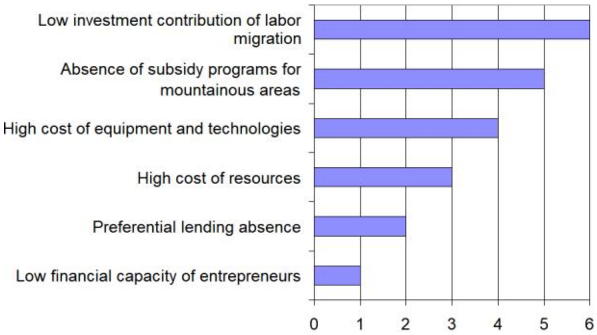


Fig. 3. Ranking of the problems of financial and resource provision of entrepreneurship in the studied territory
Source: the results of surveys of Slavsko and Skole entrepreneurs in September-October 2019.

The low financial capacity of local entrepreneurs, the absence of the possibility of preferential attraction of working capital, and the high cost of resources, equipment, and technologies stand in the way of business expansion. To conduct business activity in foothills and mountainous areas, many developed countries are trying to activate certain types of activities through the mechanism of subsidies and targeted financing of programs. In the state budget of Ukraine for 2023, it is planned to introduce a separate line for mountainous territories, and the Ministry of Development of Communities and Territories of Ukraine could already co-finance such projects.

In the territories of the mountainous areas of the region, there is practically no activity to support the functioning and further development of the institutional business infrastructure. The objective reasons for this situation are as follows:

- lower financial and investment provision due to the territorial distance from the regional center;
- features of the structure of the economy, due to relief, natural, and climatic features;
- lack of personnel (especially labor professions) due to the proximity to the border and high labor migration of the population;
- under exploitation of the potential of the territories' development, including through the implementation of business projects by small and medium-sized business entities.

The level of attracting funds from international technical assistance programs aimed at the development of small and medium entrepreneurship is insufficient. Today, local state administrations and local self-government bodies do not provide systematic stimulation of activity in this direction, and, therefore, the implementation of various projects and activities within the framework of entrepreneurship support programs having little money cannot qualitatively improve the situation regarding the development of small and medium entrepreneurship.

As for attracting loans, unfortunately, the Ukrainian banking system has not yet been able to offer appropriate products where the provision of loans for the development of a separate territory could be accompanied by certain forms of guarantees from the authorities representing this territory. The system of attracting funds for regional development through obtaining loans by business entities needs improvement. One of the directions is a search for new forms of lending under regional programs, where the interests of the state government and business would be optimally coordinated.

In the second place, the respondents noted the ambiguity, instability, and contradiction of the current legal framework of entrepreneurship, as well as the practically non-functioning nature of many legal acts, very low executive discipline concerning legal documents; the presence of many vague norms in the legislation, which can be subjected to any interpretation if desired; the unreasonableness of legal restrictions and requirements contained in separate legal acts.

For the development of entrepreneurship, informational and consulting assistance from various support institutions is necessary. Regional development agencies of Turka, Skole, Stryi, Drohobych, and Staryi Sambir districts, which are public organizations according to their organizational and legal form, operate on the studied territory. Their operation is mainly based on obtaining financial resources for activity and is sporadic. Among the implemented projects, it is possible to note the areas implemented by the agencies in the field of information and consulting support [2]:

- provision of consultations regarding permit and registration procedures;
- promoting the attraction of investments in the development of business and rural areas;
- popularization of entrepreneurial and public initiatives among the rural population;
- provision of advice on accounting and auditing;
- spreading the idea of forming vertical-horizontal integration structures, regional clusters, and cooperatives;
- provision of legal support and assistance to business entities;
- participation in the preparation and implementation of regulatory legal acts, and program documents for the development of entrepreneurial activity and rural areas;
- organization of the exchange of experience between entities of entrepreneurial activity;
- establishment of communication links between entrepreneurs, rural communities, state authorities, and local self-government bodies;
- provision of services related to the automation of production and economic processes of business entities.

The activity of these organizations is partially financed by local and state budgets, as well as foreign investors under individual projects and requires a systematic review of approaches to the formation and implementation of the state policy for the development of entrepreneurship.

The information on the possibility of starting their business is perceived by the villagers with caution and is treated with some mistrust. There are many reasons for this, they can be considered from the point of view of the degradation of the Ukrainian countryside, the lowering of villagers' standard of living, the ignoring of local initiatives, a lack of positive examples, the unstable situation on the market, as well as a lack of the state agrarian policy, experience, and conviction of the specialists-consultants themselves.

The current format of the system of information and consultation support for the rural population and entities of entrepreneurial activity in the agricultural sector of the economy, especially taking into account the processes of decentralization and the implementation of the land reform, demonstrates the unsystematic nature of the work of public sector institutions, registered agricultural advisory services, the insufficient level of the quality of services provided, a lack of qualified staff specialists, etc. Imperfect mechanisms for supporting the development of agricultural extension in Ukraine are not aimed at training interested stakeholders and practical assistance as well as the promotion of profitable activity in rural areas.

Under the conditions of an imperfect market and an unstable financial and economic situation, it is difficult for the entities of agricultural production to conduct their business profitably, it is not always possible due to the lack of information, knowledge, and the ability to obtain state support, investments, use the latest technologies, and withstand growing competition [11].

The fourth most important reason for the impact on local entrepreneurship is the significant influence of state regulatory bodies. The taxation system should be effective both for business entities and for the state. The fairness of taxation concerning the other incomes of citizens is an important aspect in the field of taxation of the incomes of natural persons of entrepreneurial activity. A simplified taxation system is an optimal way of business taxation since the general system is more complex and burdensome. The foreign practice of small business taxation is aimed primarily at its ability to create a sustainable socio-economic effect and then perform a fiscal function. The creation of a competitive environment and the prevention of minimization schemes that are actively used can facilitate the reforming of small business taxation systems, both general and simplified.

One of the elements of the imperfection of the business environment is a lack of cooperative relations among local entrepreneurs. In the project on the Concept of stimulating the development of entrepreneurship in rural areas until 2030, several factors [9] are indicated which are the main ones that shape

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the current state of local economies. Among the list of problems, there is a lack of stimulating factors for the consolidation and cooperation of small agricultural commodity producers regarding their creation of value-added chains. The topic of cooperation has a rich history, but it is very difficult to implement this movement in the mountainous and foothills areas selected for the research. As noted by Prof. Yu. Hubeni, a striking majority (76.8%) of the villagers do not see the prospects of self-management, and the share of optimists only slightly exceeds 6%. The attention of the villagers regarding cooperation in economic activity is even more impressive. More than 67% of them are not ready for economic cooperation. On the other hand, the share of optimistic (9.8%) and cautious (the answer is “perhaps”, 13%) respondents together create a sufficient basis for pro-cooperative activity [6]. The indicators of socio-economic development of the studied territory are significantly lower compared to the other areas of the region.

The substantiated issues are consistent with the visions of F. Vazhynskyi and A. Kolodiichuk, who defined the primary measures of effective support and prospects for the development of entrepreneurship at the regional level, namely [12]:

- improvement of living conditions and creation of benefits for the rural population so that they can realize their potential without moving to the city or abroad;
- formation of a favorable business climate and compliance with current legislation;
- development of entrepreneurship development strategies according to the potential inherent in the area in which such a strategy is implemented by local self-government bodies of rural communities;
- support of innovative awareness of rural residents;
- introduction of an effective financial mechanism for supporting small and medium-sized enterprises from rural budgets.

In the studied rural area, very small entities of economic activity prevail − shops (usually, food), rather primitive service enterprises, sawmills, rental points of sports and tourist equipment, and rural estates that provide tourist services, the management of which does not require significant investment costs and highly qualified personnel specialists The majority of small business owners consist of people who are not characterized by production expansion. However, in this large number of rural entrepreneurs, there could be active individuals who soon will be able to increase the efficiency of the business they lead. After all, it is known that one place created for the accommodation of one tourist provides five people with work in other spheres of life of society − supply, storage, processing, food, etc. Small rural business must be treated responsibly because it can play an important role in the development of rural areas.

**Development of rural areas in the context of non-agricultural entrepreneurship**

The multifunctional nature of rural areas is the concept of forming a village development strategy, in particular, supporting the non-agricultural activity of its residents. Local entrepreneurship is a basis of such development, first of all, which is aimed at various forms of capital attraction, on the one hand, the expansion of agricultural activity and the development of other or new agricultural production directions, and, on the other hand, the formation of business not related to the agricultural sector of the local economy [1].

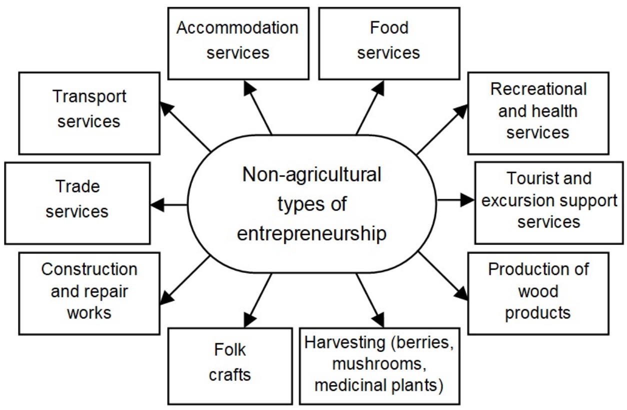


Fig. 4. Main non-agricultural types of entrepreneurship of the studied territory
Source: compiled by the authors.

Non-agricultural employment in the context of multifunctional development of rural areas is defined quite broadly and covers all types of economic activity that are related to entrepreneurial activity in rural areas, except for agriculture and forestry, hunting, and fishing. Such activities can come from agriculture and the use of natural resources through the links in the production chain. The other activities (e.g. services, trade, etc.) are similar to those found in urban areas. Natural-climatic and geographical characteristics, communication accessibility, and cultural stratum of the territory create prerequisites for the development of the main non-agricultural types of entrepreneurial activity (Fig. 4):

The reasons for the diversification of the activity of the peasant economy can be different. The most important of them is the desire to receive additional income, which is important in the conditions of low incomes of the population. Income from non-agricultural activity can be a source of financial support for a peasant family and its household. The search for additional income may be caused by the desire to make better use of available material and human resources. The question of adjusting the surplus labor force arises, especially in the winter period, when there are no other employment opportunities in the countryside.

One of the reasons for the transition to non-agricultural activities can include subjective factors, which are manifested in the desire to satisfy the needs for recognition, prestige in the rural environment, the disclosure of personal talent, and the self-realization of the peasant family. The diversification of the activity of the peasant economy in practice evidences a huge number of its forms and types. One of these forms is the provision of tourist services in rural areas, which are distinguished by attractive objects of the natural and cultural environment.

Very rarely, only in some estates, services for organizing fishing, harvesting nature’s gifts, hunting, master classes in folk crafts (pottery, pysanka studies, etc.), as well as organizing traditional folk festivities (for example, Boyko vechornytsi) are offered.

Thus, the range of additional services of the rural estate of Slavsko United Territorial Community is quite standard and limited and is often based on resources located outside the estate. Services for the organization of transportation, active rest, recreation, and health care prevail. Instead, ethnocultural, entertainment, and agro-tourism services, which play an important role in rural tourism, are practically undeveloped. It can be argued that the tourist product of rural tourism in the foothills and mountainous areas of Lviv region is rather vague and does not have a bright ethnic coloring (in contrast, for example, to Ivano-Frankivsk region, where the Hutsul coloring occupies an important place).

The offers of regional tourist products, goods, and services in the studied territory cover a rather narrow spectrum. First of all, rural estates offer recreation, traditional cuisine, health procedures, and active forms of tourist activities, which are based on external resources (climatic, landscape, balneological), often with the involvement of third-party entities. With this in mind, it is important to reorient entrepreneurs to internal resources, which are still not very involved in the creation of a tourist product. In particular, services related to traditional agro-tourism are poorly developed here.

Traditional agro-tourism includes the categories of tourist products and services directly related to the production process in a peasant or farm economy. The products and services of traditional agro-tourism may include familiarization with the technology of growing crops, animal care, primary processing of agricultural products, the direct participation of tourists in this process, the sale of own products from the garden or vegetable garden, didactic trails, agro-tourism farms, home zoo, etc. In recent years, agro-tourism entertainment and new-generation games (corn mazes, field games with the use of straw structures, various quests, geocaching, etc.) have been rapidly developing in the world. Another promising direction for rural estates of Lviv region is cultural and ethnographic tourist activities like mini Skansen (open-air museums), home museums, master classes on folk crafts and cooking of traditional dishes, village celebrations, and festivals.

Rural estates need to deepen specialization and create tourism products of a certain

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thematic direction. In particular, based on the use of Polish experience, the authors have proposed the selection of the following areas of specialization: "active recreation" (winter and summer options), "health", "family leisure", "culture and traditions", "peasant household", etc. Agro-estates specializing in one or another area should focus on providing appropriate services, which will allow them to form their image and more purposefully promote their product in the market.

The peculiarities of the development of entrepreneurship include the heterogeneity of the development of rural communities within the studied territory (Figs. 5 and 6).

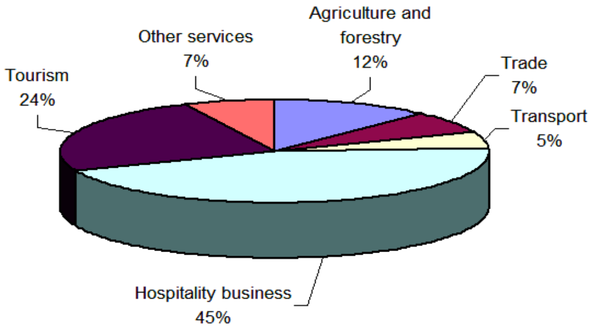


Fig. 5. Structure of the types of economic activity of small and medium entrepreneurship according to the potential of the development of Slavsko Territorial Community

Source: results of the research.

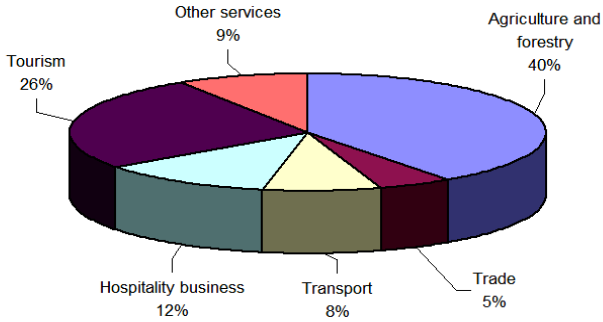


Fig. 6. Structure of the types of economic activity of small and medium entrepreneurship according to the potential of the development of Turka Territorial Community

Source: results of the research.

A high share of the tourism activity of Slavsko Territorial Community is related to natural, infrastructural, and communication factors. An important place in the promotion of tourism on the territory of the community is occupied by the National Nature Park "Skole Beskydy", which actively participates in the creation of tourist routes, ecological and educational trails, and various thematic resting places for travelers. Turka United Territorial Community does not have a developed tourist infrastructure, and forestry and tourism make up the basis of its economy.

To analyze the functioning of business objects in the field of rural tourism in the studied territory, the authors used the available information, which is presented on the Internet sites that are usually used by potential tourists to plan a trip:

1)Booking.com (https://www.booking.com/);
2)Karpaty Info (https://www.karpaty.info/);
3)Rest in Ukraine (https://ua-travel.info/ua/53/lvivska_obl.html);
4)Carpathians Travel Guide (https://turizm-karpaty.com.ua/).

The results of the analysis are presented in Table 2.

Table 2. Private estates of rural tourism (according to Internet resources)

| Name of the administrative district | Selective data of the Internet resources | | | | Estimated number of overnight places |
|---|---|---|---|---|---|
| | Booking. com | Karpaty Info | Rest in Ukraine | Carpathians Travel Guide | |
| Drohobych | 76 | 74 | 56 | 28 | 318 |
| Stryi | 240 | 452 | 307 | 175 | 2,350 |
| Sambir | 130 | 13 | 10 | 7 | 52 |
| ***Total*** | ***446*** | ***539*** | ***373*** | ***210*** | ***2,720*** |
| Other districts | 74 | 10 | 5 | 8 | 45 |
| Lviv region | 520 | 549 | 378 | 218 | 2,765 |
| Territory covered by the research, % | 85.7 | 98.1 | 98.6 | 96.3 | 98.3 |

Source: results of the research.

The Internet resource karpaty.info, which is used by the majority of potential guests, is the most popular among the owners of private estates. It should be noted that there is an increase in offers for placement in objects without a category on the global internet platform booking.com. These two platforms dominate the market for providing accommodation services in the Carpathian region. The other platforms have a much smaller database of accommodation offers, information on only selected tourist destinations, and a limited ability to apply filters to search for accommodation that would meet the individual needs of guests.

According to the data obtained from the Internet resource karpaty.info, the authors ranked the studied territory by the level of entrepreneurship in the field of providing housing services in private rural estates in newly created united territorial communities (Table 3).

The main centers of development of rural tourism in Lviv region are concentrated in mountainous and foothill areas. The absolute leader is Stryi district (82%, 452 estates), and in second and third place, respectively, are Drohobych district (14%, 74 estates), and Sambir district (2%, 13 estates).

All the other administrative districts of Lviv region account for only about 1.8% of the total number of facilities for temporary residence in rural areas.

Table 3. Ranking of the administrative objects by the level of entrepreneurship in the field of rural tourism of the studied territory

| Number of rural tourism facilities | Development level | Territorial Community |
|---|---|---|
| 0-5 | Low | Sambir, Rudky, Dobromyl, Novokalynivka, Staryi Sambir, Khyriv, Biskovychi, Raliv, Strilky, Stryiska, Zhydach, Mykolayiv, Novyi Rozdil, Khodoriv, Gnizdychiv, Zhuravno, Hrabovets and Duliby, Trostyanets, Boryslav, Drohobych, Medenychi |
| 6-50 | Average | Morshyn, Skole, Truskavets, Turka, Borynya |
| >50 | High | Koziv, Slavsko, Skhidnytsia |

Source: results of the research.

In 2 districts of the region, according to karpaty.info, there are no rural estates at all. The obtained results testify to the extremely uneven development of rural tourism in the foothills and mountainous areas of Lviv region.

***Stryi district.*** Of 14 territorial communities, the vast majority of private estates that provide rural tourism services are found in the Slavsko village and the Koziv village territorial communities. The indicator of provision with agro-estates per 1,000 people of the rural population is 8.22. The main centers of development of rural tourism in the district are the following ones: the urban-type settlement Slavsko (230 estates), the town of Skole (39), the village of Volosianka (41), Oriavchyk (20), Plavie (35), and Tuholka (8). In the rest of the settlements, there are from 1 to 5 estates. The two main factors that determine the number of agro-estates in individual settlements are the availability of ski lifts and the proximity to the international highway M-06 Kyiv-Chop. The centers such as Slavsko, Volosianka, Oriavchyk, Plavie, and Tysovets are also well-known ski resorts, so in the winter season, private estates here specialize in providing accommodation services for fans of winter recreation.

***Drohobych district.*** The district is characterized by an average level of development of rural tourism. Of 89 settlements of the district, agro-estates were found mainly in Skhidnytsia and Truskavets United Territorial Communities. The main centers are Skhidnytsia (58 estates) and Truskavets (14), which are well-known balneological resorts; in the third place is the village of Staryi Kropyvnyk (2). The development of a network of rural tourism facilities in the Drohobych district is closely related to the availability of mineral water sources and creates an alternative to hotels and sanatoriums in the region. Most of the estates in this region, along with accommodation services, also offer full board (three meals a day), sometimes even diet, and additional services include the delivery of mineral water, herbal tea, massage, the consultation of a doctor or nutritionist, and in some cases − even the treatment of certain diseases under the supervision of a qualified specialist (for example, “U Pana Tkachyshyna”, Skhidnytsia). Some estates also offer alternative services of health improvement, such as apitherapy (sleeping on beehives) or yoga.

***Sambir district.*** It is characterized by a low level of rural tourism development. There are 35 agro-estates located in 12 settlements of 67 (18%) on the territory of the district. Estates are more or less evenly spread over the entire territory of the district. The most important centers are the village of Verkhnie Husne (4), Verkhnie Vysotske (3) and Rozluch (4). From 1 to 2 estates also function in the villages of Bilychi, Velyka Volosianka, Verkhnie Vysotske, Kryiivka, Spas, Yavora, and Yasenytsia Zamkova. Picturesque mountain landscapes, a large number of monuments of wooden sacred architecture, preserved Boyko traditions, as well as mineral water springs in Rozluch, and several ski lifts are the prerequisites for the development of rural tourism in the region.

**Motivational aspects of entrepreneurial activity in the field of rural tourism**

The development of rural tourism is motivated by the fact that in recent years there have been significant changes in the preferences and behavior of vacationers; the socio-industrial and economic situation for the residents of rural areas has changed, and the awareness of preserving picturesque landscapes, folk traditions and crafts, and the environment has been revived.

The development of rural tourism depends on objective and subjective factors. The objective ones include, first of all, significant potential opportunities for organizing this form of recreation in the studied territory. In many cases, the unfavorable financial situation of the villagers and the inefficient use of labor resources cause the corresponding changes. Instead, subjective factors include the desire to raise the standard of living of the family through the diversification of an additional activity or the search for alternative incomes related to agriculture. To ensure the appropriate level of income for the majority of peasant households, primarily those with little land and the poor, it is not enough to produce only food products. Sometimes it is more appropriate to limit or even abandon agricultural activity, especially farming in mountainous areas. It is for this reason that some enterprising villagers of the mountainous and foothills part of Lviv region have ventured into providing various services, including tourist services.

For the majority of the surveyed entrepreneurs, economic needs were the main factor that prompted entrepreneurial activity. In the minds of the villagers, they have a double meaning. First, the owners of the studied rural estates needed additional means of livelihood, because farming or other activities did not satisfy the basic needs of their families; secondly, the expectations of entrepreneurs regarding the standard of living far exceeded the results of their previous activity.

The conducted studies prove that the decision to start a business activity in the field of tourism is accompanied by various motives and motivational actions (Table 4).

Field studies show that the most important motives for deciding to provide tourist services included the desire to raise the standard of living of the family, the possibility of using unengaged resources, especially housing and land, the location of the house near attractive tourist destinations, the positive practice of successful entrepreneurs, and the need to implement life plans.

Table 4. Motives for decision-making regarding the provision of tourist services of the selected objects of the Slavsko United Territorial Community

| Motives | Answers, % |
|---|---|
| Desire to increase income | 83.1 |
| Location of the household in a tourist-attractive area | 67.4 |
| Examples of positive practice (success) of neighbors and acquaintances | 63.0 |
| Possibility of realizing old ideas | 55.2 |
| Willingness to receive guests, establish communications | 43.5 |
| Impossibility of stable employment | 19.6 |
| Redundancy or layoff (retirement) | 15.2 |
| Availability of vacant living space | 12.9 |
| Family traditions of hospitality | 6.5 |
| Other | 4.3 |

Source: results of the research.

In the process of researching the motivation of Polish owners of rural estates, S. Golian concluded that over time, economic aspects become less important, instead, the importance of motives related to self-realization, meeting new people, and realizing one’s interests increases [3].

So, it can be concluded that the revenues received from the provision of tourist services by local entrepreneurs are intended for:

- stabilization of seasonal fluctuations in the standard of living of household members, which is manifested in the direction of these incomes for household purposes;
- increasing the comfort of life, thanks to equipping the household with engineering communications (water, sewerage, gas,

heating), repairing the house, and organizing the yard;

- increase in material security as a result of the purchase of modern energy-saving devices, the construction of a residential component, and the repurposing of commercial premises.

## CONCLUSIONS

The further development of non-agricultural activity requires an active state policy to promote rural entrepreneurship, the modernization and development of local infrastructure, the creation of favorable investment, and competitive and innovative conditions for the development of small and medium-sized businesses. It can be assumed that entrepreneurial initiatives will be directed to new market niches that meet the requirements of the market economy.

Non-agricultural activity is one of the most important elements of alternative incomes of rural residents and the intensification of economic activity in rural areas (in particular, foothills and mountainous) and is a subject for further scientific research.

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# LEASING ALGORITHM OF COMPULSORY CONSOLIDATION OF AGRICULTURAL LAND IN UKRAINE

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***Abstract***

*The paper studied leasing algorithm of compulsory consolidation of agricultural land in Ukraine. The analysis revealed that fragmentation of land use is one of the main destabilizing factors which deteriorate the compactness of land massifs of the enterprise and cause growing production costs in the process of commercial activity. This situation leads to strip farming, and the non-use of such lands prevents rational management of the land plots being in the use of one person. The data regarding the normative monetary valuation of agricultural land plots outside the settlement was received through electronic services by the State Service of Ukraine for Geodesy, Cartography and Cadastre. The results reveal the algorithm of exchanging land plots as the main instrument of land consolidation in Ukraine. Development of the approaches to exchange of land plots along with redistribution of them enables immediate arrangement of land plots by making agreements. It facilitates simple consolidation of lands and creates conditions to solve the problems of land fragmentation.*

***Key words*****:** *land lease, land consolidation, land fragmentation, land massif*

## INTRODUCTION

In Ukraine, land reform started in 1990, with the following expectations: denationalization and privatization of the land of former collective farms, establishment of different forms of ownership and farming on the land, ensuring equitable development of the land, introduction of the market of agricultural land, and increased level of efficient exploitation of agricultural land, creating an efficient mechanism for the improvement of natural conditions and protection of agricultural areas [9].

Among the problems which agricultural producers face today, a particular focus is on the impossibility to cultivate fields as single land massifs because of so-called "checkerboard" (within one field there are land plots that are owned by one land owner and are cultivated by him/her, also land plots which are abandoned, and/or "others" land plots which are owned by other people and cultivated by other land users -land owners).

Currently, massifs of agricultural land in Ukraine are heavily partitioned and it is impossible to cultivate the small land plots by using large agricultural machinery. It is the consequence of the partitioning of 27.5 million ha of agricultural land (66% of the total area of agricultural land in Ukraine), which have been divided into land plots (shares) with an average size of 4 ha.

Therefore, a massif of agricultural lands with an average area of 100 ha is partitioned into dozens of land plots that are owned by dozens of people and several land users. Consequently, it is very difficult for farmers to avoid strip farming, i.e. the situation when a person has the right to use land plots within one massif of land but they do not have common boundaries. Thus, it is impossible to shape and cultivate the integral massifs of land.

Consolidation of agricultural lands is the next step declared in the land reform after adoption of the law on turnover of agricultural lands. Farmers have long demanded consolidation of agricultural lands, and land users apply different algorithms of exchange to optimize using land plots and to accumulate integral massifs of land.

## MATERIALS AND METHODS

The present research discloses the algorithm of exchanging land plots as the main instrument of land consolidation in Ukraine. Development of the approaches to exchange of land plots along with redistribution of them enables immediate arrangement of land plots by making agreements. It facilitates simple consolidation of lands and creates conditions to solve the problems of multi-purpose consolidation.

The theoretical and methodological basis of the research is made by a complex of methods, namely dialectic, system analysis, synthesis, cartographic, structural and functional analysis.

The information basis of the research is created by the current legislative and regulatory documents, electronic services of State Service for Geodesy, Cartography and Cadaster, State Statistics Service of Ukraine, and works of domestic and foreign scientists who studied the issue of land consolidation.

The study was conducted on the land use of Liuvais Private Company which is located within the area of Monastyryshche territorial community in Uman district of Cherkasy region (Fig. 1).

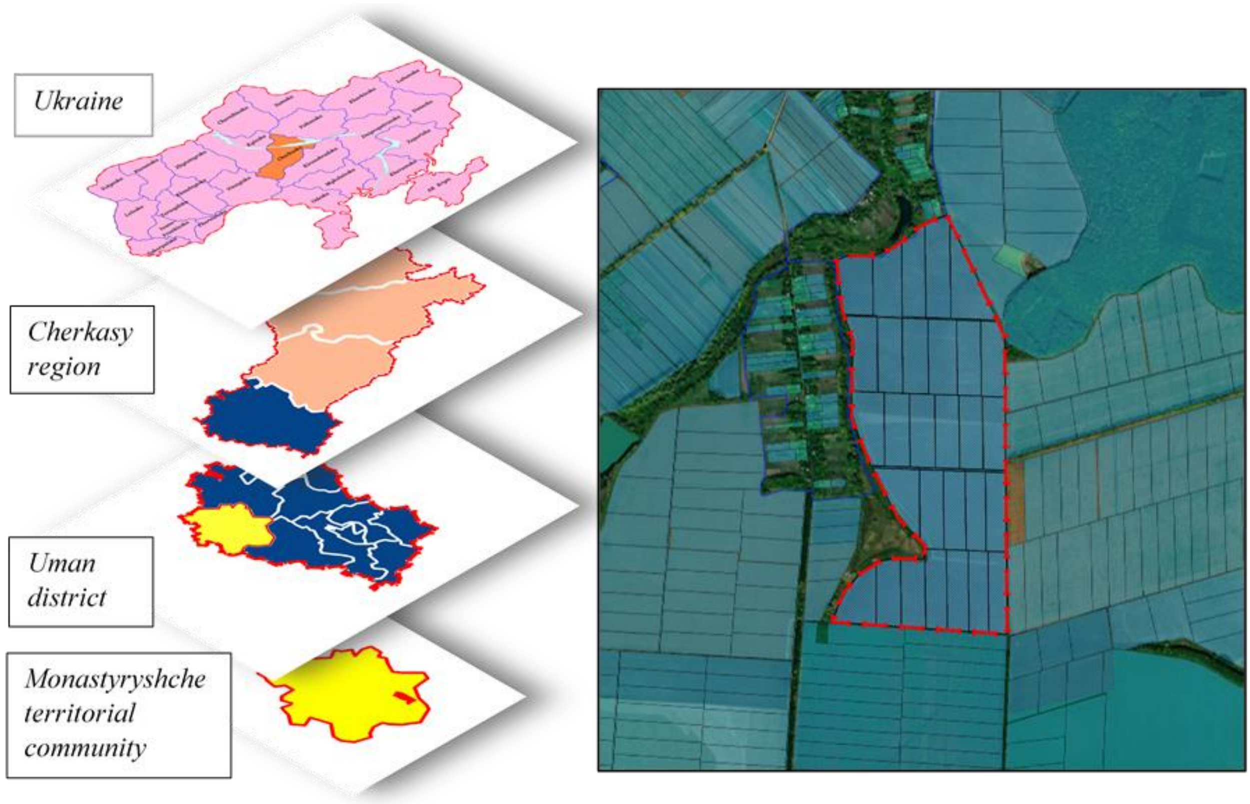



Fig. 1. Study area – territory of the of Liuvais Private Company (Monastyryshche territorial community in Uman district of Cherkasy region)*
*Source: Completed by the authors according to the data [12].

The Liuvais Private Company has been running its activity since 2002. It is specialized in growing cereals (except rice), legumes and oil seeds. To run its business, the Liuvais Private Company cultivates the land massifs with the total area of 100 ha used according to the lease agreements with 29 shareholders.

Fragmentation of land use is one of the main destabilizing factors which deteriorate the compactness of land massifs of the enterprise and cause growing production costs in the process of commercial activity.

## RESULTS AND DISCUSSIONS

Nowadays, Ukraine greatly focuses its efforts on implementation of the European integration course, performance of international-legislative obligations, including the issues of development of local and regional democracy [10].

Land consolidation has proven to be an important instrument of rural development in Europe. It can enable farmers to become more competitive by removing fragmentation of parcels, and by allowing them to expand the size of their holdings [6].

Farmland fragmentation has generally been considered as negative for agricultural production and food security and equivalent to the increase in production costs leading to farm inefficiency [2, 8].

Land consolidation is a highly effective land management tool that allows for the improvement of the structure of agricultural holdings and farms, which increases their economic and social efficiency and brings benefits both to right holders as well as to society in general [17].

According to the recommendations of the Food and Agriculture Organization (FAO) of the United Nations for the Eastern and Central Europe, consolidation of lands is identified as an improvement of the structure of land plots to avoid the effect of fragmentation of lands for more efficient multi-purpose use of the rural area by balancing the demands of agriculture, landscape planning, environmental protection, recreation and transportation, particularly when the area is needed for building roads of particular importance [7] (Fig. 2).

Land consolidation – in whatever design is a powerful tool for solving structural problems and land use conflicts in rural areas [15] and an important planning tool for implementing environmental and rural development policy [16].

Consequently, most contemporary agricultural land policies aim to reduce fragmentation through land consolidation as a panacea to farmland fragmentation [3, 18].

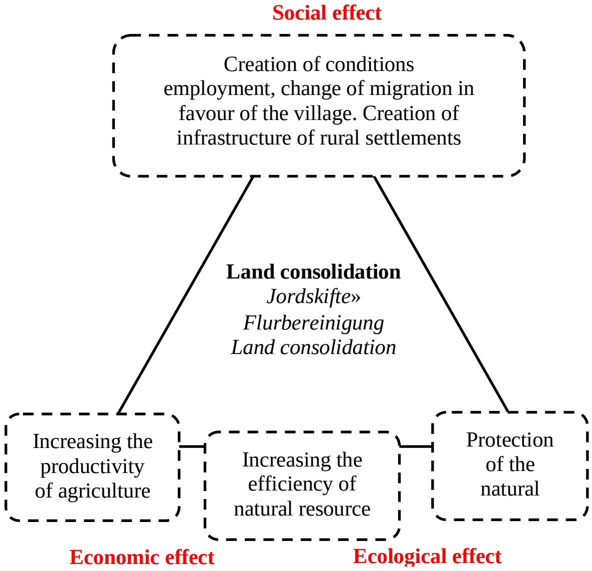



Fig. 2. Concept of land consolidation according to FAO*
*Source: Completed by the authors according to the data [4, 7, 11].

Besides the classical land consolidation programs, other instruments such as voluntary land parcel exchange, land banking and cooperative farming, were used to combat farmland fragmentation.

Fragmentation in land use is present when a single farm enterprise cultivates several plots (regardless of whether owned or leased) located in different places. Fragmentation of this type can hamper the efficiency of management and production because plot sizes are small and this imposes constraints on cropping and use of technology. Land leasing is widely used to circumvent this problem and to consolidate land [5].

Practice and traditions using different types of land consolidation models (voluntary or compulsory, simplified or complex) and well written legislation (with clear goal and objectives) provides encouragement for land owners to participate in land consolidation projects [14].

Land lease has long been the principal mechanism of land consolidation in Ukraine. Since January 1, 2019 the Law of Ukraine №2498 has entered into force and created regulatory fundamentals for improvement of the rules of land use in the massifs of agricultural land, particularly the opportunity to exchange the leased land plots.

The exchange can be applied referring to the land plots of all forms of ownership and is implemented by mutual agreements of lease or sublease of land plots. Therefore, owners and lessees of agricultural land plots located in the massif of agricultural land can exchange their rights to using land plots for the period of the lease agreement [13].

A massif of agricultural land – is a complex of land plots of agricultural purpose which consists of agricultural and non-agricultural land plots necessary for servicing them (land plots under field roads, melioration objects, commercial ways, runs, linear objects, objects of engineering infrastructure, as well as ravines, marshy lands, other lands which are situated within the land massif), have common boundaries and limited natural and/or artificial topographic elements (motor ways of common use, field protecting forest belts and other protecting planting, water objects, etc.) [1].

Hence, a massif of agricultural land can be defined as a complex of agricultural land plots (two and more) which have common boundaries and create a single area that is limited by field protecting forest belts and/or roads (including field ones). The appropriate information about it should be introduced into the State Land Cadastre. Thus, only partitioned land plots within one massif can become the objects of exchange.

The agreements on exchange of the rights to using lands can be concluded concerning the land plots which are intended for commercial agricultural production, farming activity and private farms. The agricultural land plots intended for private farms and farming activity located within the massif of agricultural land can be used by their owner or user for running commercial agricultural production without changing the purpose of such land plots.

The current legislation provides for the mechanism of forced exchange of the rights to land plots in the land massif initiated by the person holding the right to use a significant part of the agricultural land massif (at least 75% of all lands of the massif) [13].

A significant land user has the right to lease or sublease other agricultural land plots located in the massif on the condition of transferring them to the owner or lessee of another land plot located in the same massif for the same period and under the same terms, in case that non-use of such land plots because of strip farming creates obstacles for the rational use of the land user's land plots.

The right to lease (sublease) land plots that is acquired by a person who has the right to use a significant part of the massif of agricultural land, in exchange for transferring the right to use another land plot, and is exercised with the following specificities:

(1)The term of the lease (sublease) should not exceed the term of the land plot use according to the agreement concluded in exchange.

(2)The size of the lease payment (payment for sublease) should correlate with the lease payment (payment for sublease) mentioned in the agreement concluded in exchange.

(3)The lessee does not have the preemptive right to purchase the leased land plot in case it is on sale.

(4)The lessee (sublease holder) does not have the right to get reimbursement for improvement of the leased land plot from another party of the agreement, as well as for extension of the agreement for the next term in case of objections of the other party of the agreement.

(5)In case there is no easy access from the edge of the massif to the land plot, the right to which is transferred in exchange, the person holding the right to use a significant part of the massif of agricultural land should ensure the land user's passage on foot and by vehicles to the land plot on the conditions of free easement.

(6)In case a person who holds the right to use a significant part of the massif of agricultural lands gets the right to lease (sublease) several land plots that belong to one owner, the land plots he/she proposes in return should have common boundaries.

On the studied area, the Liuvais Private Company has above 75% of the massif of land in its possession and therefore, has the right to use the newly introduced institute of land plot exchange because of strip farming. The owner of the land plot with the cadastral number 7123485700:03:001:0275 and area of

3.7086 ha, which is located within the massif of land, refused to extend the lease relations with the Liuvais Private Company and made decision to cultivate the land plot himself. The enterprise does not object and recognizes the owner's right to cultivate the land plot himself. However, the mentioned land plot is situated in the middle of the massif of land cultivated by the Liuvais Private Company and thus, the consequent strip farming cause difficulties in land treatment.

The mentioned drawbacks in land management cause additional costs for operation of agricultural machinery and loss of yield because of growing different agricultural crops on the same field and treatment with chemical agents that can make damage them as each of crops needs specific chemical elements that are not good for others.

Moreover, location of the land plot with the cadastral number 7123485700:03:001:0275 in the center of the massif of land creates difficulties and sometimes cultivation of it is loss-making because agricultural machinery can pass the way to the land plot only across the lands that are leased and cultivated by the Liuvais Private Company. In addition, the piece of land under the pathway to the land plot is not tilled that is also economically inexpedient and unprofitable for both parties as the land is getting covered with harmful and dangerous weeds.

Because of strip farming, the non-use of such lands prevents rational management of the land plots being in the use of one person. To avoid the obstacles for rational land management in the studied massif of land, the land plots should be exchanged.

The algorithm for exchanging the rights to use land plots in the massif of agricultural land has four stages.

***1. A significant land user appeals in written form to the owner (lessee) of the land plot with the proposal, where he/she identifies the land plots which he/she has the right to use and proposes to exchange, and the amount of property damage due to such exchange.***

The following is attached to the proposal:

- a draft agreement of lease (sublease) signed by one party;
- a draft agreement of lease (sublease) of the land plot, the right to use which is proposed to be transferred in exchange, signed by one party;
- a certified copy of the agreement of lease of the land plot (if the significant land user is also the lessee of the land plot the right to use which is proposed to be transferred in exchange).

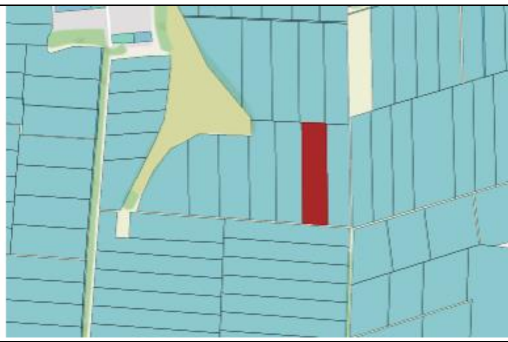
According to the known approaches, modeling of redistribution is usually preceded by the exchange of land plots, equal in area, with consideration of the soil quality or violation of price within the set permissible range.

At that stage, it is determined that the normative monetary value of the land plot with the cadastral number 7123485700:03:001:0275 accounts for UAH 136403.83. The land plot with the cadastral number 7123485700:03:001:0295 which has the area of 3.0595 ha and the normative monetary value of UAH 126,504.04 is proposed for exchange. It is located in the mentioned massif of land, but on the edge that enables its cultivation without the necessity to cross the mainland area, significantly facilitates the cultivation of the whole massif and reduces the risks of making harm while treating the land with chemical substances.

The land plot with the cadastral number 7123485700:03:001:0295 proposed for exchange is in the use of the Liuvais Private Company on the right of lease according to the land lease agreement №881 of 27 November 2017 concluded by the land owner for the period of 10 years with the set lease payment of 4.5% of the normative monetary valuation annually (Table 1).

Examination of the size of land plots and their normative valuation shows that the land plot proposed for exchange is by UAH 9,899.79 cheaper than the land plot with the cadastral number 7123485700:03:001:0275, but such difference accounts for only 7.26% of its price. Such a difference in value is permitted by law.

Table 1. Characteristics of the land plots proposed for exchange*

| | | |
|---|---|---|
| Configuration |  |  |
| The cadastral number | 7123485700:03:001:0275 | 7123485700:03:001:0295 |
| Area, ha | 3.7086 | 3.0595 |
| Normative monetary value, UAH | 136403.83 | 126504.04 |

*Source: Completed by the authors.

In addition, referring to the category of lands, i.e. agricultural lands, and the type of lands, i.e. arable land, the land plot is free of real estate objects and thus, its evaluation and amount of reimbursement have not been determined.

To reimburse the price difference, the Liuvais Private Company proposed and mentioned in the agreement the condition of compensation for losses that can occur because of such difference in the form of the annual payment of 4.5% of the difference that accounted for UAH 445.50 at the time the agreement was concluded.

***2. Within one month from the day of receiving the offer, the owner or lessee is obliged to consider the appeal and sign the lease (sublease) agreement or provide a written reasoned refusal to conclude it.***

To avoid strip farming and to ensure efficient use of land, the Liuvais Private Company appeals to the owner of the land plot having the cadastral number 7123485700:03:001:0275 with the proposal to make an agreement of sublease of a similar land plot in that massif of land, but at its edge. However, the land owner can reject the proposed conditions of exchange.

In case of a negative or unreasoned response, or no answer, the Liuvais Private Company can claim to a court because the enterprise runs its economic activity in the field of growing commercial agricultural products on the leased lands within the administrative borders of Monastyryshche territorial community in Uman district and is a significant land user.

The law "On Land Lease" clearly defines the cases when the conclusion of an agreement in court is not allowed, particularly:

- if the land plot belongs to the area of perennial plantations and perennial plantations are laid on it;
- if real estate objects are located on the land plot;
- if the land plot belongs to non-agricultural lands of agricultural purpose (except for field roads located inside the massif of agricultural lands);
- if the land plot has common boundaries with the massif of agricultural land and its location does not create overlapping for the person who has the right to use a significant part of the massif of agricultural land;
- if the land plot is located in a different massif of agricultural land than the one transferred for use in exchange;
- if the land plot does not belong to the category of lands for commercial agricultural production, personal farms or farming activity;
- if the land plot has a different composition of land and topography;
- if the land plot has a normative monetary value, which differs from the normative monetary value of the land plot transferred for use in exchange by more than 10 percent.

The Liuvais Private Company has made numerous proposals to make an agreement according to which the land owner will get a similar land plot in the same massif of land to lease, but at the edge, while the Liuvais Private Company will cultivate his land plot in exchange. In all cases, the land owner refused the proposals of the Liuvais Company based on his property rights. However, in this legal relationship, the property rights are not a sufficient basis for refusal to conclude the agreement of land plot exchange.

Thus, the land legislation approves that in case of negative or unreasoned refusal, or no reply, the initiator may apply to the court. As a result, the Liuvais Private Company is forced to make a claim to the court on the issue of concluding such an agreement through judicial procedure.

The court's decision to recognize the lease (sublease) as concluded is the basis for state registration of the right to lease (sublease) the land plot in accordance with the law.

***3. State registration of the right to lease (sublease) a land plot in accordance with the procedure prescribed by law.***

The information on exchange of the right to use land plots should be introduced as additional data to the State Register of Property Rights to Immovable Property in the description of the object of property right with identification of the subject acquiring the right and the period of exchange.

Although the agreements of exchange of the rights to land plots are compulsory, the information introduced into the State Register of Property Rights to Immovable Property will provide additional defense for land users from land raiding and threats of land squatting.

***4. Written notification of the lessor.***

Lessees of land plots must notify the lessor in writing on the exchange within five days from the date of state registration of the right to sublease. The written notice shall be sent to the lessor by registered letter with acknowledgment of receipt or delivered with a receipt.

## CONCLUSIONS

The regulations introduced in Ukraine to ensure exchange of the rights of using land plots by concluding mutual agreements of lease or sublease of the corresponding land plots between land users have provided the opportunity for land consolidation. However, in practice, the procedure needs improvement to settle the following problem issues:

(1)It is difficult to implement the norm of acquiring the status of a significant land user to get the right of using other land plots in the massif of land. It is because of the red tape procedure of inventory of the massifs of agricultural land and spending costs for shaping all land plots located in the massif of land even if the significant user is not interested to use them.

(2)The current legislation enshrines the opportunity to exchange the rights to use land plots that are located within one massif of land. In practice, however, it is often needed to exchange land plots which are located in different massifs of land in order to consolidate agricultural land of land users.

(3)The legislation approves exchange of the rights only by concluding agreements of lease and sublease of land plots. It is not considered in the law that land plots within one massif of land can be objects of the right of emphyteusis or the right of permanent use which cannot be transferred for the secondary using.

Considering present realities, the market of property rights will be limited in the nearest years and agricultural producers will continue to acquire the right of using land plots. Hence, it is necessary to develop mechanisms of agricultural land consolidation to satisfy the demand of amalgamation of agricultural land plots, as well as needs of land owners or land users. Therefore, consolidation of agricultural land should be performed in one or several possible ways:

- exchange of land plots;
- exchange of the rights of using land plots;
- purchase of land plots;
- amalgamation of adjacent land plots;
- changes of the boundaries and arrangement of land plots;
- change of the category and/or the purpose of land plots use;
- other ways in compliance with the laws.

It is also worth noting that people who intend to consolidate agricultural land plots should individually choose the acceptable way considering if they are land owners or land users and if they can acquire the property right of agricultural lands. Moreover, it is extremely important to control the legally enshrined opportunity of exchange of the rights to using agricultural land plots does not violate the rights of land owners and land users.

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# INFLUENCE OF THE SEASON AND GENOTYPE OF GOATS ON THE QUALITATIVE COMPOSITION OF THEIR MILK

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***Abstract***

*To study the effect of seasonality and genotype on the productivity of goats and the quality of their milk, 30 goats of three different breeds were taken: 10 Saanen goats, 10 Russian white goats and 10 local Ukrainian goats. The milk yield of the experimental goats was evaluated during the year for the volume, protein content, fat content, lactose content, acidity and density. The effect of both genotype and season on protein content, and the effect of only season on fat content and lactose content were determined. The most dependent on seasonal factors (change of season, temperature fluctuations, amount of precipitation) were goats of Saanen and Russian white breed, the least dependent were goats of local Ukrainian selection. Acidity and density of milk did not change during the entire experiment. The highest protein content (3.32%) and fat content (3.37%) were found in Saanen goats. The highest lactose content (4.53%) was found in goats of local Ukrainian breeding. During the spring and summer months, goats of local Ukrainian selection and Russian white showed the best productivity.Goats of the Saanen breed had the best productivity during the autumn and winter months.*

***Key words*****:** *goat's milk, fatty acid composition, seasonal effects, milk productivity of goats*

## INTRODUCTION

The global goat population continues to grow and currently exceeds one billion. The number of goats raised primarily for milk production is also increasing due to increased demand [30]. In European countries, the share of goat milk is about 30% of the total amount of milk produced, and in Arab countries it reaches 50% or more [13]. In recent years, there has also been a trend towards increasing demand for goat's milk in Ukraine. Since 2011, there has been an increase in the number of goats [40]. The leading place in the world belongs to dairy and combined dairy, and meat breeds at 37% and 20% respectively of the total number of breeds. At the same time, milk (66.4%) and milk-meat (15.9%) goat breeds predominate in Europe, and combined make up more than 50% in Asia and Africa. The largest number of breeds, 374, come from Europe, of which 59 are from Italy, 27 from Germany, 23 from Spain, 20 from Great Britain and 18 from France [41].

The positive effect of goat's milk on human health has long been known, and today its study is deepening. This product has excellent nutritional properties, is easily absorbed by the body, and the complete protein composition ensures the maximum use of essential amino acids to meet the anabolic needs of the body [26]. It has been proven that the composition of fatty acids in goat milk affects human health and directly affects the taste of dairy products [10, 11, 37]. In particular, it was previously reported, that saturated fatty acids increase the likelihood of cardiovascular disease. In addition, it is known that conjugated linoleic acid reduces the generation of cancer cells and inhibits atherosclerosis and diabetes [4]. In addition, a higher amount of some short-chain fatty acids enhances the goat scent and the aftertaste of dairy products [14, 38].

Animals of the *Saanen* breed and its crossbreeds with local goats represent most of the dairy goats in Ukraine. However, there are few purebred goats of the *Saanen* breed [12]. *Saanen* goats are considered one of the most productive dairy goat breeds in the world. With good care and feeding conditions, *Saanen* goats over 2.5 years of age can give a total of 700–900 liters of milk per milking during the lactation period [9]. At the same time, there is information about a large number of local crossbreed goats both abroad and in Ukraine, the productive characteristics and quality of milk of which, compared to goats of common breeds, under certain conditions prevail over the latter [27]. Despite the proven facts of the high productive qualities of goats of known breeds, there are alternative studies that have established the superiority of local goats, in particular alpine goats, over analogues of the *Saanen* breed. According to data [42], goats of the specified breeds had differences in the list of chemical components. Goats of the *Alpine* breed prevailed over goats of the *Saanen* breed both in terms of protein content by 1.33 g/100 g, fat content by 1.45 g/100 g, and ash content by 0.06 g/100 g, respectively, and they also prevailed by profiles fatty acids. Similar conclusions were reached by other scientists, who noted that the milk of Mediterranean red and Ionica breeds was richer in phosphorus (P) than in Maltese and in zinc (Zn) than in Maltese, Girgentan and *Saanen* breeds [6]. In addition, similar results are noted for the peculiarities of local Ukrainian goats improved by the *Saanen* breed, in which the content of fat, protein and dry matter was higher by 1.63, 1.52 and 2.95%, respectively, compared to the production of purebred goats of the *Saanen* breed [32]. The economic effect of introducing the use of local goats is more pronounced in countries with a lower income level of the population, where their breeding allows the maintenance of the income level of households and provides the population with inexpensive products [24]. It is known that the characteristics of local goats allow them to be kept in areas with a difficult arid, mountainous or tropical climate, where the placement and breeding of purebred goats will not have a consistently high result due to their insufficient adaptation [3]. Usually, in countries where goat breeding is widespread, high adaptability to the environment is one of the main characteristics of local goat breeds and crossbreeds, in developed countries most goats have genetically selected breeds for high productivity [31].

Productivity and quality of milk, meat, wool and other products of both purebred and cross-breed goats depend on the same factors. However, the strength of the relationship between factor and dependent features will be significantly different for different combinations of them. Determining the most influential factors that have the most significant impact among others will intensify the production of goat products. However, many scientists have their own vision of this issue and, accordingly, obtain results that do not completely satisfy both manufacturers and the scientific community and, accordingly, encourage further multifaceted research.

Thus, we can note that there is still no unanimous view on the detection, assessment and peculiarities of possible dependence between the quality indicators of milk of purebred and crossbred goats and the known factors influencing them.

The purpose of the study was to compare the dependence of quality indicators of milk raw materials obtained from different cross-breed goats of Ukrainian origin, and seasonal local factors, taking into account the influence of genotypic characteristics of the experimental herd.

## MATERIALS AND METHODS

### *Biological material*

To solve the tasks set in the work, a scientific research experiment was conducted to determine the quality indicators of milk raw materials obtained from goats of different breeds, taking into account the season of the year and changing weather conditions (global warming).

The object of our research were lactating goats of local Ukrainian selection (Group I), Russian white breed (Group II) and *Saanen* goats (Group III) in the amount of 10 heads in each group. Goats were kept in experimental conditions of a separate room (vivarium) on the territory of Sumy National Agrarian University, Sumy region, Ukraine. The vivarium we use is intended for growing and breeding laboratory animals, including goats used in scientific work or the educational process. The premises are provided with conditions for humane maintenance, which includes feeding, drinking, maintaining favorable healthy exercise and lactation, maintaining microclimate parameters within the approved norms. When selecting goats for the experiment, the generally accepted principle of matching pairs was followed by age, live weight, and term of the goats. Each of the groups of goats was kept in identical conditions before and during the experiment.

For this study, goats with an average live weight of 58.7–61.5 kg, milk productivity per lactation 691.81–725.23 kg, and a yield of kids per 100 ewes of 175–180% were selected. All procedures were carried out in accordance with the guidelines of the Council Directive 86/609/EEC [5] on the protection of animals used for experimental and other scientific purposes.

***Feeding and rearing conditions***

In the vivarium, goats were kept on deep litter, the floor area per head was 1.10–1.15 m$^2$. Animals had constant access to fresh water.

Goats were fed according to the norms of vivarium rations, which provided the following indicators:

1.The structure of the diet for three groups of lactating goats at vivarium was: rough – 27%, juicy – 49%, concentrated – 24%;

2.The level of digestible protein per 1 feed unit (Metabolizable Energy (ME)) was 110.5 g;

3.The energy content of rough age is 0.5 fodder unit (Metabolizable Energy (ME)) (26%), juicy feed was 0.4 feed unit (21%) and concentrated feed was 1.0 feed unit (53%);

4.Feed price was 0.62 (€/kg) for the production of 1 kg of milk;

5. Feed cost was 0.94 (€/kg);

6.The level of dry matter based on 100 kg of live weight was 3.3 kg;

7.Energy nutritional value of dry matter of the diet was 1.0 foodunits (MetabolizableEnergy-ME);

8. The ratio of calcium to phosphorus was 1.5:1.

***Analysis of the physical indicators***

Milk productivity was determined by daily milking followed by monthly and lactation calculations in mid-April and mid-May. Duration of lactation of goats was 305 days. Milksamplesweretakenfromgoatsaccordingto ISO 707:2008 [19]. Samples of milk taken in proportion to the daily milk yield in 2 adjacent days from each of the experimental groups on the farm were filtered and cooled to a temperature of +6±2ºC and analyzed within 24 hours after milking. Milk samples were taken exclusively from healthy goats that did not show any symptoms of possible diseases.

***Analysis of the chemical indicators***

Samples for assessing the quality of milk were taken during each of the four seasons of the year twice a month.

The study of the chemical composition of milk was carried out at the testing center of the Animal Husbandry Institute of the National Academy of Sciences, which is accredited according to the requirements of ISO/IEC 17025:2006) [16], certificate No. 2T621 at the National Accreditation Agency of Ukraine. In order to evaluate the energy value of milk and its technological properties, its chemical composition was determined. In the laboratory of the institute, milk samples were heated to a temperature of +40 ºC, homogenized on the device Milk Homogeniser HF-0.5/25 (OHFU, China), which is certified according to ISO 9001:2008 [22]. The chemical composition of milk based on the content of mass fraction (mol) of dry matter (DM), fat (F), true protein and total protein, lactose, dry fat residue (DFR) was determined by infrared spectrometry (ISO 9622:1999) [23]. The reference methods for calibrating the infrared analyzer Thermo Nicolet NEXUS 670 (GMI, USA) according to mass fractions fat content was determined according to ISO 18252:2006 [15]. Total and true protein content was determined according to Kjeldahl method (ISO 8968-1:2014, ISO 8968-5: 2001) [20, 21]. Lactose content was determined according to method of high-performance liquid chromatography (ISO 22662:2007) [17]. Dry matter content was determined accordingto ISO 6731:2010 [18]. The expanded uncertainty of U measurements at calibration k = 2, p = 0.95 was 0.06, respectively; 0.04, 0.03, 0.12 and 0.08%.

Based on the obtained data, the ratio of nutrients in milk, which characterize its technological properties, was calculated and the energy value of milk raw materials was estimated, based on the fact that 1 kg of milk contains 9.5 g fat, 4.4 g protein, 3.74 g lactose. Also, during the experiment, the peculiarities of the influence of weather factors on the milk productivity of goats of the *Saanen* breed, Russian white breed and goats of local Ukrainian selection were studied, namely the following weather factors were studied: air temperature and precipitation.

***Statistical analysis***

We analyzed the results of our research in the MS Excel 2010 editor using common statistical procedures, two-factor analysis of variance and construction of a mathematical model using the method of the smallest frames. All indicators (n = 24) were compared using Student's t-test. The significance of the differences was confirmed under the condition of $p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$.

***Ethical approval***

During the experiment, we used appropriate methods of treating goats to reduce their pain or discomfort. The recommendations of the International Committee on Animal Ethics and the requirements of the Law of Ukraine No. 692 of 2008 "On Humane Treatment of Animals" and the Law of Ukraine No. 3447-IV of 2006 "On Protection of Animals from Cruelty" were taken into account when conducting the experiment. The university's control body of Ethical and Humane Treatment of Animals in Scientific Research granted permission to use goats (BT-21-0210-02).

## RESULTS AND DISCUSSIONS

According to its physico-chemical and microbiological indicators, goat milk has a rather complex structure and is significantly different from the milk raw materials of other animals. Goat milk is a complex polydisperse system in which water is the dispersion medium. Most of the nutritional components of goat's milk are in various colloidal, emulsion and molecular states. Ionic solutions of goat milk consist of milk sugar and mineral components. Breed, lactation characteristics of goats and seasonal factors affect the content of proteins, fats and lactose in goat milk.

Better absorption of goat's milk in the human gastrointestinal tract is due to the size of its fat globules (with a size of 2 µm). Thus, breed composition and genetic features, as well as environmental conditions significantly affect the milk productivity of dairy goats.

Our research shows that in April, the first month of lactation, fluctuations in the ambient temperature of 13°C (from +8 to +21°C) were observed (Fig. 1).

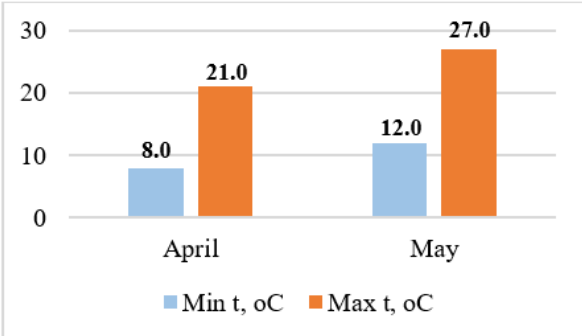


Fig. 1. Temperature extremes of the studied period ($^0$C)
Source: Own calculations.

Fluctuations in average daily milk yield in the control group of goat amounted to 1.21 kg (from 1.45 to 2.66 kg), in the II experimental group 1.25 kg (from 1.50 to 2.75 kg), in the III experimental group 1.31 kg (from 1.55 to 2.86 kg).

The maximum daily yield in the control group I was noted at an ambient temperature of +20°C, in the II experimental group at +19°C, in the III experimental group at +18°C. The minimum daily yield in the control group was recorded at a temperature of +9°C, in the II experimental group – at +10°C, in the III experimental group at +8°C (Fig. 2). In May, in the second month of lactation, daily temperature fluctuations of the environment were 15°C – from +12 to +27°C. Fluctuations in average daily milk yield in the control group of goats amounted to 1.28 kg (from 1.61 to 2.89 kg), in the II experimental group – 1.03 kg (from 1.99 to 3.02 kg), in the III experimental group – 1.01 (from 2.01 to 3.02 kg). The minimum production of goats of the control and experimental groups was noted at a temperature of +12°C, the maximum was noted at a temperature of +25°C in goats of the control group and at +23°C in goats of the II research group and at +21 °C in goats of the III research group (Fig. 2).

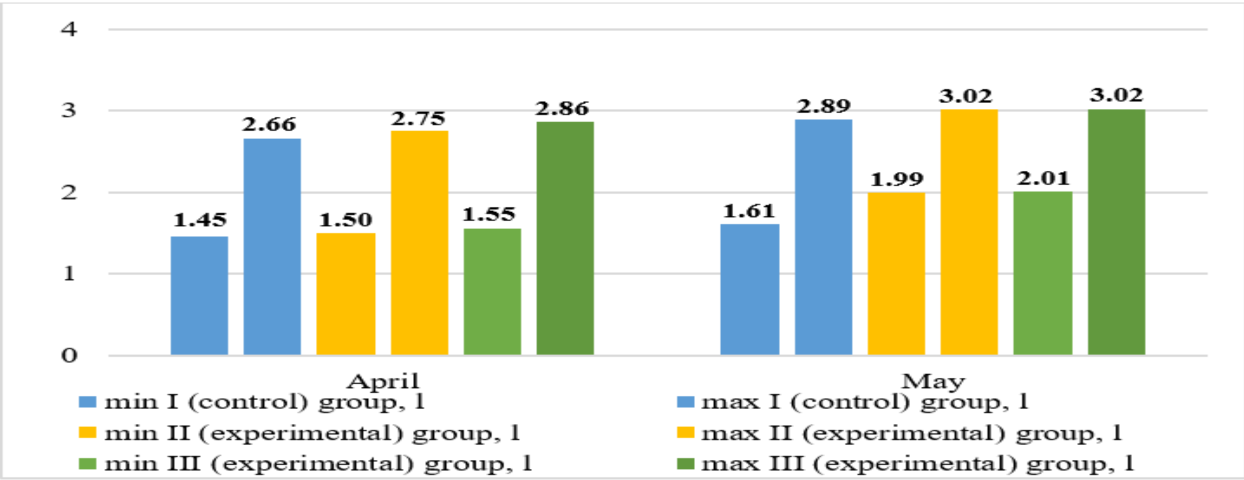


Fig. 2. Extremes of milk productivity of goats under the influence of temperature fluctuations
Source: Own calculations.

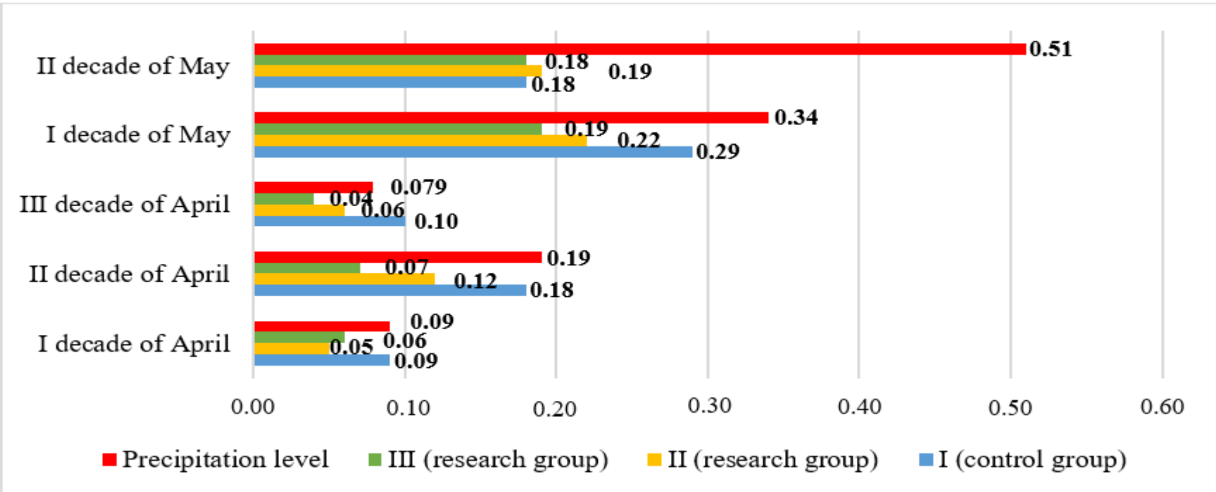


Fig. 3. Dynamics of milk productivity of goats during precipitation
Source: Own calculations.

The decrease in milk productivity, regardless of the ambient temperature, was influenced by atmospheric precipitation (Fig. 3).

Precipitation in the first decade of April did not exceed 9.0 mm. At this time, the average milk yield of goats local Ukrainian selection decreased by 0.09 kg. Goats of the Russian white breed also showed a decrease in milk yield in this decade by 0.05 kg. A similar tendency towards a decline in milk yield was also manifested in the herd of *Saanen* breed by 0.06 kg.

Milk yields of goats remained low during the 2nd decade in response to a gradual increase in precipitation to 19 mm.

Goats of the local Ukrainian selection had this amount of milk for 10 days at the level of 0.18 kg, which was more than Russian white counterparts by 0.06 kg and more than peers of local *Saanen* breed by 0.11 kg.

In the third decade of April, there was a decrease in precipitation to 7.9 mm, as a result of which there was a less significant decrease in milk yield, in particular, in goats of the *Saanen* breed by 0.1 kg, in their counterparts of the Russian white and local breeds of Ukrainian selection by 0.06 and 0.04 kg respectively.

In May, there was a seasonal increase in precipitation, and in the first decade of the month, its level was already 0.34 mm. At the same time, there was a decrease in the milk productivity of goats in the control group to 0.29 kg, in the II experimental group to 0.22 kg, and in the III experimental group to 0.19 kg. During the second decade of May, the tendency to increase the amount of precipitation remained. Rainfall was recorded at 51 mm over 10 days. At the same time, the experimental herd showed a decrease in average milk yield, but with a lower intensity, as there was a gradual increase in temperature in this decade of the month, compared to previous periods, which had a positive effect on milk yield indicators. But all the same, goats of the *Saanen* breed showed a decrease in milk yield by 0.18 kg, their peers of the Russian white breed reacted with a decrease of 0.19 kg, and ewes of the Ukrainian breed of local selection did not give 0.18 kg of milk.

Thus, we can state that with an increase in the amount of precipitation, the lactation of goats was characterized by a decrease in the volume of milk. Goats of the *Saanen* breed reacted more sensitively to an increase in the level of precipitation and showed the highest values of insufficient milk, at the same time, their counterparts of Ukrainian local selection were less affected by weather seasonal fluctuations and reduced productivity the least among animals of the three groups. Therefore, during the work on increasing the yield of dairy goats, natural and climatic factors should be taken into account. This is especially relevant when goats are kept using a grazing system, and when planning to increase milk yield, the influence of such factors as environmental temperature and precipitation should be minimized as much as possible. Therefore, in bad weather, it is advisable to additionally feed goats indoors or under a canopy to avoid a sharp decrease in milk yield.

Analyzing the data in the table. 1, it should be noted that in a temperate climate at the end of summer, goat milk has the lowest levels of fat and protein and the highest levels of active acidity. Research has established that the *Saanen* breed of goats had the highest protein content recorded in autumn 3.46%, which is higher than spring milk by 0.14% ($p < 0.001$), summer milk by 0.30% ($p < 0.001$) and winter milk by 0.12% ($p < 0.001$). The fat content in the milk of goats of local Ukrainian breeding was higher in the fall (3.52%) compared to the spring months by 0.11% ($p < 0.001$), compared to the summer months by 0.74% ($p < 0.001$) and compared to the winter months by 0.17 % ($p < 0.001$). Goats of the I control group showed the highest lactose content in the cold winter season (4.45%). This was higher than the spring season by 0.04% ($p < 0.001$), higher than the summer season by 0.09% ($p < 0.001$) and higher than the autumn season by 0.14% ($p < 0.001$). The protein content in the milk of goats of the Russian white breed reached in the fall exceeded the indicator of the spring season by 0.13% ($p < 0.001$), exceeded the indicator of the summer season by 0.28% ($p < 0.001$), and exceeded the indicator of the winter season by a 0.08% ($p < 0.001$). Goats of the Russian white breed showed the highest fat content in the autumn months compared to the spring months by 0.30% ($p < 0.001$), compared to the summer months by 0.78% ($p < 0.001$) and compared to the winter months by 0.33 % ($p < 0.001$). The highest lactose content was found in goats of this breed in the winter season (4.55%), which was higher compared to spring indicators by 0.03% ($p < 0.001$), summer indicators by 0.05% ($p < 0.001$), autumn indicators by 0.08% ($p < 0.001$).

The protein content in the milk of goats of local Ukrainian selection in the spring was lower than in the autumn by 0.14% ($p < 0.001$), in the summer it was inferior to the autumn indicators by 0.31% ($p < 0.001$), and in the winter it lagged behind the winter protein content by 0.10% ($p < 0.001$).

The milk of goats of the *Saanen* breed had a fat content greater than the fat content during the spring season by 0.11% (p <0.001), higher than in the summer months by 0.75% (p <0.001) and higher compared to the winter indicators by 0.16% (p<0.001).

*Saanen* breed goats also showed a higher lactose content in winter relative to spring content by 0.04% (p <0.001), relative to summer content by 0.09% (p <0.001), relative to autumn content by 0.14% (p <0.001). So, on average, the protein content during the year changes by 0.08–0.31%, the fat content by 0.11–0.78%, the lactose content by 0.03–0.14%. At the same time, the protein content and lactose content are subject to smaller changes during the seasons of the year, since these components of milk are more thinly and evenly dispersed compared to the fat content. Fatcontent (0.11–0.78%) undergoes the biggest changes according to the seasons of the year. Protein content and lactose content change less, since these components of milk are more thinly and evenly dispersed compared to fat content, and their changes are less influenced by paratype factors. The percentage of protein content ranges from 0.08 to 0.31%, and the lactose content varies from 0.03 to 0.14%. Acidity and density of milk almost do not change depending on the season.

Table 1. Seasonal changes in goat milk indicators (n = 24)

| Indicator | Season | | | |
|---|---|---|---|---|
| | **spring** | **summer** | **autumn** | **winter** |
| **Group I (Ukrainian selection local goats)** | | | | |
| Protein content, % | 3.00±0.0010$^{***b}$ | 2.83±0.0011 | 3.14±0.0016$^{***acd}$ | 3.04±0.004$^{**a***b}$ |
| Fat content, % | 3.41±0.0015$^{***bd}$ | 2.77±0.0013 | 3.52±0.0018$^{***abd}$ | 3.36±0.002$^{***b}$ |
| Lactose content, % | 4.53±0.0013$^{**b***c}$ | 4.49±0.009 | 4.45±0.0011$^{***b}$ | 4.56±0.009$^{**a***bc}$ |
| Acidity, °T | 14–15 | 15–16 | 14–15 | 14–15 |
| Density, g/cm$^3$ | 1.028–1.029 | 1.026–1.027 | 1.026–1.027 | 1.028–1.029 |
| **Group II (Russian white goats)** | | | | |
| Protein content, % | 3.24±0.008$^{***b}$ | 3.09±0.0010 | 3.37±0.008$^{***abd}$ | 3.29±0.006$^{***ab}$ |
| Fat content, % | 3.33±0.0012$^{***bd}$ | 2.85±0.0013 | 3.63±0.0016$^{***abd}$ | 3.30±0.008$^{***b}$ |
| Lactose content, % | 4.2±0.0012$^{***bc}$ | 4.50±0.0011$^{***c}$ | 4.7±0.0015 | 4.55±0.003$^{***abc}$ |
| Acidity, °T | 14–16 | 14–15 | 15–16 | 14–16 |
| Density, g/cm$^3$ | 1.027–1.028 | 1.026–1.027 | 1.026–1.027 | 1.027–1.028 |
| **Group III (*Saanen* goats)** | | | | |
| Protein content, % | 3.32±0.011$^{***b}$ | 3.16±0.009 | 3.46±0.006$^{***abd}$ | 3.34±0.004 |
| Fat content, % | 3.51±0.013$^{***b**d}$ | 2.88±0.012 | 3.62±0.021$^{***abd}$ | 3.45±0.008$^{***b}$ |
| Lactose content, % | 4.50±0.008$^{**b***c}$ | 4.45±0.009$^{**d}$ | 4.40±0.010 | 4.54±0.003$^{***abc}$ |
| Acidity, °T | 14–16 | 15–16 | 14–16 | 15–16 |
| Density, g/cm$^3$ | 1.028–1.029 | 1.026–1.027 | 1.026–1.027 | 1.028–1.029 |

* – P < 0.05; ** – P < 0.01; *** – P < 0.001;
Source: own calculations.

Using two-factor analysis of variance, the influence of genetic belonging to the three experimental groups and the influence of seasonal factors on the protein content of milk was determined. It was established that the factor of the season reliably influenced the protein content ($F_{season}$ 296.84>$F_{-critical}$ 2.61) with a power of 26.46%. The influence of goat breed on milk protein content was also statistically probable ($F_{season}$ 701.32>$F_{-critical}$ 3.00), which formed a dependent trait at the level of 41.67%. The interaction of the specified factors did not have a reliable effect on the amount of protein, and other unaccounted factors caused its changes with a strength of 31.73% (Fig. 4). The results of the effect of season and genotype and their interaction on the fat content in goat milk were statistically reliable. Thefatcontentinthemilkoftheexperimentalherd ofgoatsprobably ($F_{season}$ 1013.40>$F_{-critical}$ 2.61) by 71.95% depended on seasonal factors. The factor of influence of the genetic belonging of goats on the fat content had statistical reliability ($F_{genotype}$ 35.42>$F_{-critical}$ 3.00) and influenced the specified indicator with a power of only 1.08%. The influence of the interaction of season and genotype factors on the fat content of goat milk was statistically significant ($F_{\text{-factor interaction}}$ 7.64>$F_{\text{-critical}}$ 2.10) at a level of no more than 1.67%. Ignored factors caused a change in the studied indicator with an influence of 25.27% (Fig. 5).

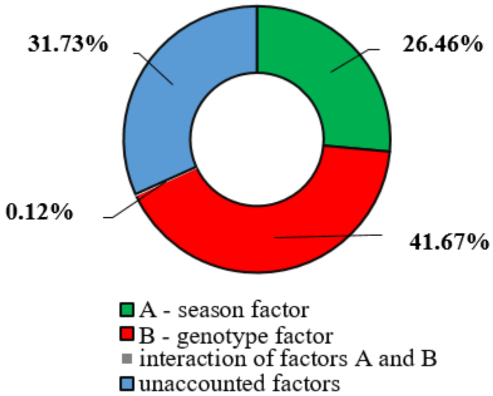


Fig. 4. The influence of season and genotype of goats on protein content
Source: own calculations.

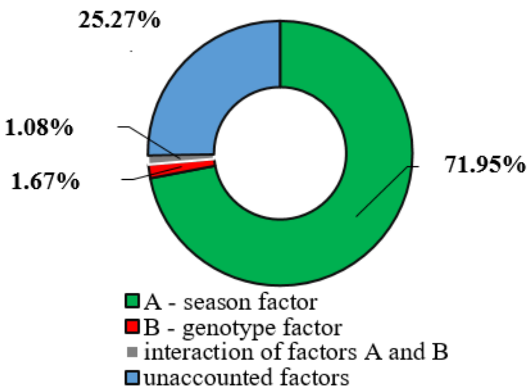


Fig. 5. The influence of season and genotype of goats on fat content
Source: own calculations.

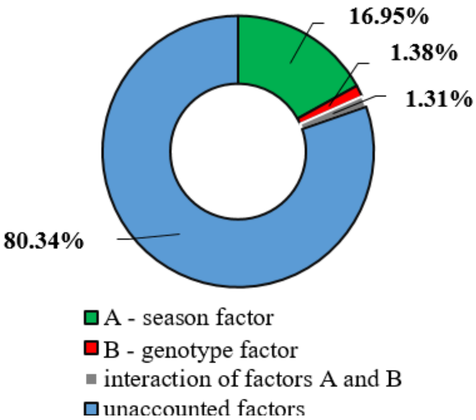


Fig. 6. The influence of season and genotype of goats on lactose content
Source: own calculations.

A probable influence ($F_{\text{season}}$ 75.14>$F_{\text{-critical}}$ 2.61) of seasonal factors on the lactose content was established at the level of 16.95%. The effect of the goat genotype on the specified indicator was also statistically confirmed ($F_{\text{genotype}}$ 9.18>$F_{\text{-critical}}$ 3.00) and reached a value of 1.31%. The interaction of the factors of the season and breed of goats probably ($F_{\text{-factor interaction}}$ 2.90>$F_{\text{-critical}}$ 2.10) influenced the lactose content in their milk with a force of 1.31%. Ignored factors caused a change in the studied indicator within 80.34% (Fig 6).

Thus, we observe the presence of a confirmed influence of both seasonal and genotypic factors and their interaction on the protein content, fat content and lactose content in the milk of goats of all three groups at once with different strengths, however, it should be noted that on animals of each individual breed they can affect differently.

In order to study the dependence of the content of protein, fat and lactose on seasonal factors, namely, on the influence of the temperature of the natural environment, data analysis was carried out by constructing a two-dimensional linear mathematical model using the method of least squares.

Therefore, using the indicated two-dimensional linear mathematical model built by the method of least squares (Table 2), an analysis of the presence and closeness of the linear relationship between protein content indicators and changes in temperature indicators during the seasons in all experimental goats was carried out. As a result, it was found that in goats of the *Saanen* breed, the relationship between the indicated indicators was not reliable ($F_{\text{est}}$ 0.0022<$F_{\text{crit}}$ 1.1898), and therefore the dependence of protein content on temperature changes was not confirmed.

At the same time, it was proved that goats of the Russian white breed showed a statistically reliable ($F_{\text{est}}$ 1.8530>$F_{\text{crit}}$ 1.1898) dependence of the protein content indicator in their milk on temperature fluctuations of the environment, which was confirmed by the value of the pair correlation coefficient, which showed a moderate ($0.3<r_{xy}<0.5$), inverse ($r_{xy}<0$) relationship between indicators for goats of this group. And this shows that with the increase in average daily temperatures, the protein content in the milk of these goats decreases.

At the same time, no statistically significant relationship was established between the protein content in the milk of goats of the Ukrainian local breed and the fluctuation of the temperature regime during the year ($F_{est}$ 01709<$F_{crit}$ 1.1898), which indicates some adaptation of the animals of the specified group to the effect of seasonal factors on the protein content in their milk.

Table 2. Statistical data of a two-dimensional linear mathematical model by the method of least squares

| Indicator | Protein content | | |
|---|---|---|---|
| | **Group I** | **Group II** | **Group III** |
| F estimated value of Fisher's test, $F_{est}$ | 0.0022 | 1.8530 | 0.1709 |
| F critical, $F_{crit}$ | 1.1898 | 1.1898 | 1.1898 |
| Pairwise correlation coefficient, $r_{xy}$ | -0.4920 | -0.6097 | -0.3642 |
| Coefficient of determination, $R^2$ | 0.2421 | 0.3718 | 0.1309 |

Source: own calculations.

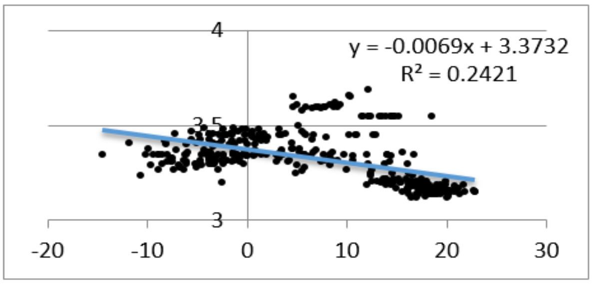


Fig. 7. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

The evaluation of the coefficient of determination based on the established inverse dependence shows that 0.24% of the variance of the effective characteristic of the protein content in the milk of *Saanen* goats could be caused by a change in the factor characteristic: the temperature regime, and the rest of the variance could be caused by the influence of random factors (Fig. 7). The coefficient of the inverse linear regression equation shows that for every 1°C increase in temperature, the protein content could proportionally decrease by 0.0069% (Fig. 7). However, the value of the coefficient of determination was not likely for the mentioned control group, so this is only a guess.

At the same time, the study of the coefficient of determination under confirmed inverse dependence for the population of goats of the Russian white breed allows us to state that 0.37% of the change in the protein content of their milk is caused by the change in temperature indicators during the year, and the remaining 99.63% of the indicator variation is caused by other factors. The analysis of the mathematical expression of the dependence between the specified indicators shows that when the ambient temperature increases by 1°C, the protein content in milk will reliably decrease by 0.0089% (Fig. 8).

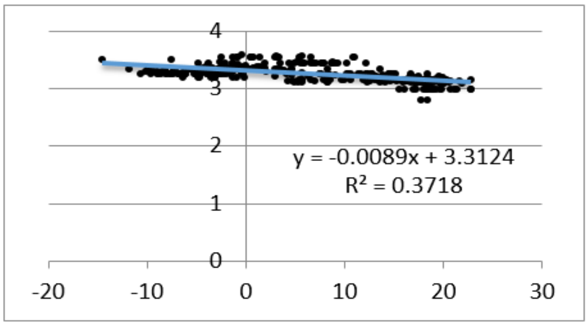


Fig. 8. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in Russian white goats
Source: own calculations.

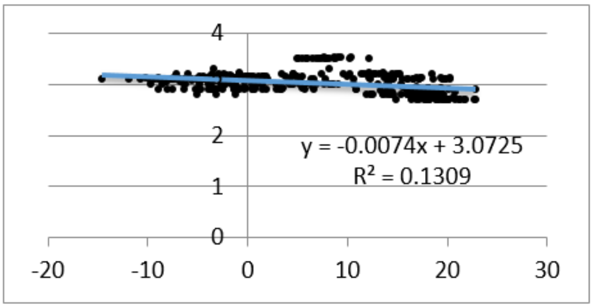


Fig. 9. Linear approximation of the dependence of protein content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

The analysis of the coefficient of determination based on the revealed inverse regression showed that 0.13% of the possible protein content in the milk of goats of the Ukrainian local breed could be formed by the effect of the factor of temperature changes during four seasons, if we detected its reliable influence. And according to the values of the coefficient of the inverse linear regression equation, an increase in temperature by 1°C could cause a decrease in the protein content by 0.0074% (Fig. 9), but this judgment cannot go beyond the limits of assumption.

Therefore, we can state that the protein content depended on natural temperature fluctuations only in goats of the Russian white breed, and in goats of the *Saanen* and Ukrainian local breeds, such a dependence was not observed.

The assessment of the interdependence between the fat content in milk and the change in temperature during the studied period showed a noticeable ($0.5<r_{xy}<0.7$), inverse ($r_{xy}<0$) and statistically significant ($F_{est}>F_{crit}$) relationship between the specified indicators for goats of all experimental groups. And this shows that with the increase in the average daily temperature, the fat content in their milk decreases significantly (Table 3).

The found coefficient of determination indicates that for goats of the *Saanen* breed, 0.31% of the changes in the resulting characteristic (fat content) was formed by the behavior of the factor characteristic (by the temperature level), and the rest of the changes depend on unaccounted random factors (Fig. 10).

Table 3. Statistical data of a two-dimensional linear mathematical model by the method of least squares

| Indicator | Fat content | | |
|---|---|---|---|
| | Group I | Group II | Group III |
| F estimated value of Fisher's test, $F_{est}$ | 10.3338 | 8.3393 | 8.2747 |
| F critical, $F_{crit}$ | 1.1898 | 1.1898 | 1.1898 |
| Pairwise correlation coefficient, $r_{xy}$ | -0.5643 | -0.5742 | -0.6262 |
| Coefficient of determination, $R^2$ | 0.3121 | 0.3298 | 0.3922 |

Source: own calculations.

Observation of the coefficient of the inverse linear regression equation made it possible to state that for each decrease in the ambient temperature by 1°C, the fat content in milk will proportionally increase by 0.0199% (Fig. 10).

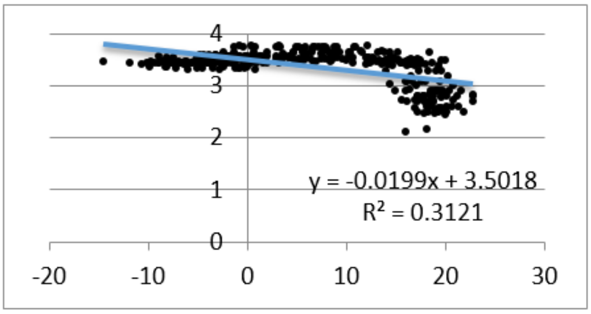


Fig. 10. Linear approximation of the dependence of fat content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

The calculated coefficient of determination for the mathematical expression of the variability of the fat content in the milk of goats of the Russian white breed under the influence of seasonal temperature fluctuations revealed that the dependent trait was formed by the action of the factor by 0.32%, and by the action of other unidentified factors by 99.68%. Taking into account the obtained coefficient of the inverse linear regression equation for this model, we can say that if the external seasonal temperature drops by 1°C, the fat content in the milk of these goats will increase by 0.0199% (Fig. 11).

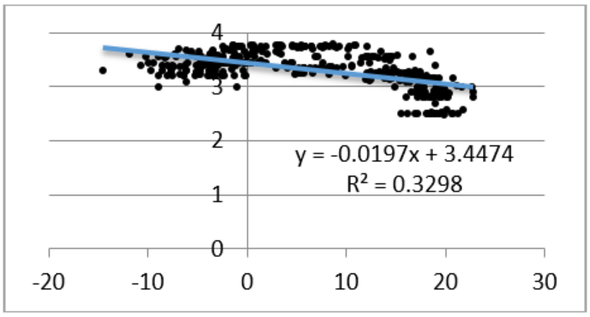


Fig. 11. Linear approximation of the dependence of fat content on changes in average daily temperatures during the year in Russian white goats
Source: own calculations.

The obtained coefficient of determination for the description of the dependence between the fat content in the milk of goats of the Ukrainian local breed and changes in the external temperature indicates that 0.39% of changes in the dependent characteristic was formed under the influence of the factor, and the rest (99.61%) of its changes was formed under the influence of extraneous, unassessed in this study factors. Calculations of the coefficient of the inverse linear regression equation established that if the natural temperature decreases during the day by 1°C, the fat content in milk will increase by 0.0213% (Fig. 12).

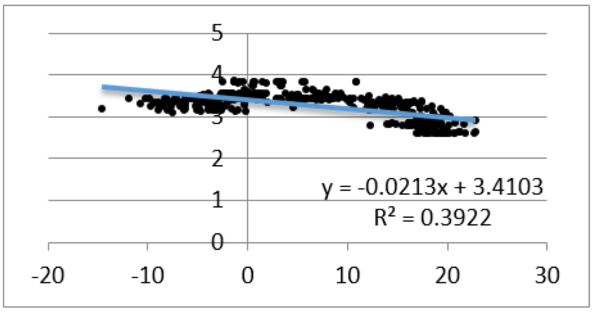


Fig. 12. Linear approximation of the dependence of fat content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

Thus, we can say that the fat content in milk depended most strongly on changes in environmental temperature in goats of the Ukrainian local breed, and the least in goats of the *Saanen* breed.

Table 4. Statistical data of a two-dimensional linear mathematical model by the method of least squares

| Indicator | Lactose content | | |
|---|---|---|---|
| | Group I | Group II | Group III |
| F estimated value of Fisher's test, $F_{est}$ | 1.1327 | 1.1327 | 2.7297 |
| F critical, $F_{crit}$ | 1.1898 | 1.1898 | 1.1898 |
| Pairwise correlation coefficient, $r_{xy}$ | -0.4594 | -0.5200 | -0.2878 |
| Coefficient of determination, $R^2$ | 0.2111 | 0.2704 | 0.0828 |

Source: own calculations.

Further research on the dependence of the content of milk components on changes in the temperature regime during the seasons of the year using a two-dimensional linear mathematical model using the method of least squares (Table 4) revealed a linear relationship between the indicators of the lactose content and temperature fluctuations. At the same time, no statistically significant relationship between dependent and factor traits was established in goats of both the *Saanen* breed and the Russian white ($F_{est}$ 1.1327<$F_{crit}$ 1.1898).

However, it was found that goats of the Ukrainian local breed were distinguished by the presence of a reliable dependence between the lactose content and changes in ambient temperatures ($F_{est}$ 2.7297>$F_{crit}$ 1.1898). And the pairwise correlation coefficient for indicators of the lactose content in the milk of goats of this group showed a weak ($0.1<r_{xy}<0.3$) and inverse ($r_{xy}<0$) relationship with fluctuations in daily temperature indicators. And this signals an increase in the level of lactose in milk when the temperature drops.

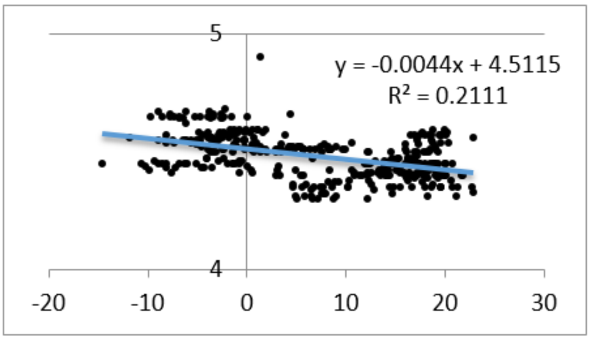


Fig. 13 Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in *Saanen* goats
Source: own calculations.

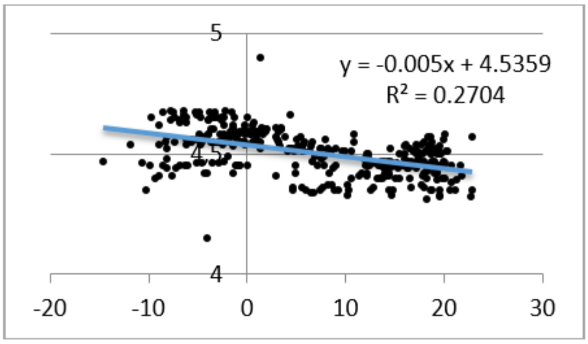


Fig. 14. Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in Russian white goats
Source: own calculations.

The value of the coefficient of determination revealed the potential dependence of the lactose content indicator in the milk of *Saanen* goats by 0.21% (Fig. 13) on the influence of temperature indicators throughout the season.

And changes in temperature by 1°C could lead to changes in lactose content by 0.044%, however, reliable confirmation of such a relationship was not found (Table 4).

The possible dependence of the lactose content in the milk of goats of the Russian white breed on changes in seasonal temperatures could be at the level of 0.27% (Fig. 14), which would be manifested in a symmetrical decrease of the dependent characteristic by 0.005% when the factor characteristic increases by 1°C. But such a potential dependence was not confirmed statistically (Table 4).

The coefficient of determination specified for the dependence of the lactose content in the milk of goats of the Ukrainian local breed on the temperature regime reflected the influence of the factor characteristic on the dependent one at the level of 0.08%, while 99.92% of the remaining changes in the indicator were formed under the influence of extraneous factors (Fig. 15).

The coefficient of the inverse linear regression equation for this model shows that if the daily temperature of the environment decreases by 1°C, the lactose content in the milk of goats of this group will increase by 0.004%.

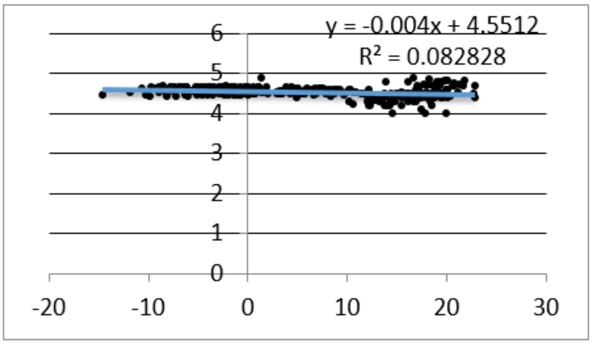


Fig. 15. Linear approximation of the dependence of lactose content on changes in average daily temperatures throughout the year in goats of local Ukrainian breeding
Source: own calculations.

Therefore, the seasonal dynamics of the lactose content in milk was reliably, albeit at a weak level, formed by seasonal temperature fluctuations only in goats of the Ukrainian local breed. In animals of other breeds, the lactose content in their milk did not depend on the temperature factor.

According to the obtained data, we established that goats of the *Saanen* breed in the spring season had higher indicators of protein content and fat content, respectively, by 9.64% ($p<0.001$) and by 2.85% ($p<0.001$), but lower indicators of lactose content at 2.95% ($p<0.001$) relative to goats of the Ukrainian local breed. These results completely contradict other findings [32], which indicated that local Ukrainian goats improved with the *Saanen* breed had higher fat, protein, and dry matter content by 1.63%, 1.52%, and 2.95%, respectively, compared to products of purebred *Saanen* goats. The same identical predominance of *Saanen* goats over Ukrainian local goats was noted in the results of our research during the rest of the year.

In contrast to the publication [29], we found a probable effect of seasonal factors on the lactose content, fat content and protein content of goat milk, which was consistent with reports [25, 34, 44].

Our conclusions did not coincide with the data [35, 39] about the predominance of the influence of genotypic factors on milk productivity of goats, as we established its effect in the range of 1.08–41.67%, which was less than the effect of seasonal factors, which was in in the range of 16.95–71.95%. Although, in general, this result of ours coincided with the opinion [2], which noted the influence of genotype on the content of protein, fat and lactose in goat milk as statistically reliable, but it did not coincide with the essence of another publication [33], which rejected the presence of the influence of the genotype of goats on the specified indicators.

At the same time, the conclusions of our research on the results of factor analysis do not contradict alternative data [1, 7, 8, 28, 36, 43], but indirectly confirm them, since we monitored the influence of unaccounted factors on the composition of goat milk at the level of 25.27–80.34%, among which the influence of the type of feeding and ration, age of goats, number of lactations, stage of lactation, milking time and others remained directly uninvestigated.

Based on the analysis of the closeness of the connection between the influencing feature (seasonal factor) and dependent features (the content of protein, fat and lactose in milk) using a two-dimensional linear mathematical model by the method of least squares, it was established that the connection between them turned out to be weak ($0.1<r_{xy}<0.3$), moderate ($0.3<r_{xy}<0.5$) or noticeable ($0.5<r_{xy}<0.7$). Thus, our data are similar to other published results [25, 34], but the latter spoke about the established relationship of probably high density between the specified features ($0.7<r_{xy}<0.9$).

## CONCLUSIONS

As a result of the experiment, it was established that the productivity of goats of the *Saanen* breed, Russian white and local Ukrainian selection, had a tendency to decrease in the cold season and to increase in the warm season.

During the change of seasons, the maximum fluctuations were recorded in the fat index from 0.11% to 0.78%. Indicators of protein content and lactose content showed less variability. The protein content index ranged from 0.08 to 0.31%, and the lactose content ranged from 0.03 to 0.14%. Indicators of acidity and density of the milk almost did not change during the studied period. The highest content of protein and fat in milk was in goats of the *Saanen* breed 3.32% and 3.37%, respectively. The highest lactose content was found in goats of local Ukrainian selection 4.53%.

It was established that the protein content in milk depended on the season by 26.46%, on the genotype by 41.67%, and on unaccounted factors by 31.73%. Fat content depended on seasonal factors by 71.95% and on unaccounted factors by 25.72%. Lactose content depended on the season factor by 16.95% and on unaccounted factors by 80.34%. The statistical analysis of the data by constructing a two-dimensional linear mathematical model using the method of least squares showed that the fat content in milk depended most strongly on changes in the ambient temperature in goats of the Ukrainian local breed, and the least in goats of the *Saanen* breed. The protein content depended on natural temperature fluctuations only in goats of the Russian white breed, and in goats of the *Saanen* and Ukrainian local breeds such a dependence was not observed. The seasonal dynamics of lactose content in milk was reliably, albeit at a weak level, formed by seasonal temperature fluctuations only in goats of the Ukrainian local breed. In animals of other breeds, the lactose content in their milk did not depend on the temperature factor.

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# EFFECT OF ORGANIC AMENDMENTS ON THE VEGETATIVE DEVELOPMENT OF OKRA (*ABELMOSCHUS ESCULENTUS* L. *MOENCH*) AT DIFFERENT WIND'S DIRECTIONS

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***Abstract***

*Three different heights of prevailing wind: 0 m, 1 m and 2 m and two organic treatments (poultry manure, PM and rice bran, RB) were used. Organic treatments were divided into eight, namely 5 tons/ha RB (RB5), 10 tons/ha RB (RB10), 5 tons/ha PM (PM5), 10 tons/ha PM (PM10), 5 tons/ha each of RB and PM (RB5PM5); 10 tons/ha RB and 5 tons/ha PM (RB10PM5); 5 tons/ha RB and 10 tons/ha PM (RB5PM10), 10 tons/ha RB and 10 tons/ha PM (RB10PM10) at 3 × 2 × 6 × 3 factorial with control experiment. Measured were plant height, number of leaves, number of branches, stem girth. Results revealed that RB5PM10 yielded tallest plant (27.5 ± 8.15 cm), high number of leaves (15.75); highest leaf area (397.50 ± 18.22 cm$^2$); stem girth (1.70 ± 6.25 cm), all at 1 m wind height, respectively translating to 48.64, 0.01, 47.22 and 21.43% more than their corresponding values in control experiment. Application of RB and PM in ratio 1:2 respectively to soil enhanced all yield components and vegetative development provided heights of okra are maintained at 1 m from soil surface for winds' effectiveness.*

***Key words*: *growth, heights, poultry manure, rice bran, yield***

## INTRODUCTION

The tender green pods of okra (*Abelmoschus esculentus* L) are important sources of vitamins: A, B1, B3, B6, C and K, folic acid, potassium, magnesium, calcium and trace elements such as copper, manganese, iron, zinc, nickel, and iodine [4]. These properties are often lacking in the diet of people in most developing countries. The fruit also contains 86.1% moisture, 9.7% carbohydrate, 2.2% protein, 0.2% fat, 1.0% fiber and 0.8% ash [6]. The tender fruits are also popular for their medicinal values as they contain very high levels of antioxidants including xanthin, and lutein [19]. It also helps in stabilizing blood sugar levels and assists in controlling the rate at which the sugar is absorbed in the body. Okra is important soup delicacy because of its nutritive values that are present in the leaves and fruits [2]. Okra as a soup is a delicious lubricant for "swallows" Swallows are solid food made from *gari*, yam flour, cassava flour, pounded yam or cassava (*fufu*) and of recent grounded maize mix with flour called semo-vita. Some people among Yoruba ethnic nation like soup of tender okra leaves than its soup made from its fruits and that is why boosting its production is not out of line.

A well – drained sandy loam soil with a pH range of 6.0 - 6.8 is preferred for the cultivation of okra. Many research works have revealed that okra performs excellently well when organic manure is applied. [20] demonstrated an excellent use of pig slurry to improve chemical properties of degraded soil and plant nutrient uptake (nutrient plant uptake). In the face of current global warming, there is a need for improving on better production techniques toward crop yield increment. These may be in the climatic modifications/integration at the crop surfaces and especially temperatures and humidities control at crops' surface through wind's movements at different heights.

Wind has been known to affect crops in several ways both at lower and higher velocities [5, 1]. Generally it was found that long exposure to strong winds causes morphological changes, hot wind may results in dwarfing due to desiccation of plant tissue and reduced growth [1]. Many physiological processes, from the emergence of seedlings to fruit development and maturity depend on the quantity and quality of the light and wind that crops were exposed [7]. Application of shading net is one of the important factors that greatly influence the growth and yield of okra [10]. Some of the questions that this research work will answer are; would there be any yield difference when various avenues of wind exposures to crops in term of wind's height to the soil surface are applied. Would wind's movements near crop's surfaces if it is really worked on, may positively affect temperature and humidity near crop leaves and may increase their vegetative productivities.

Previous works have also been carried out on the study of light intensity on the photo regulation of plant [22, 9, 11], but very little work has been done on wind speeds and directions on the growth or physiology of okra and most especially in combination with different organic amendments. It has therefore become necessary to develop alternative ways to boost okra production under different planting orientation to the prevailing wind's direction as a means of contributing to boosting food supply especially as global warming is now a threat to food security in the world. Hence, this research work evaluated the vegetative growth of okra by analyzing variation patterns and relationships among the ratio of nutrient source using qualitative characters when crops are exposed naturally to differing wind's speeds at different heights from the ground surface.

## MATERIALS AND METHODS

The field experiment was conducted at the Teaching and Research Farms of the College of Agriculture, Osun State University, (Latitude 7$^o$, 52'28.37"N and Longitude 4$^o$, 18'13.76"E) Ejigbo campus from late May to August, 2019. The climate is typically rain forest type with two peaks of rain (bimodal rainfall) which is between 1,158 mm-1,250 mm per annum. The temperature regime is high all the year round with mean of 28 °C-33°C, relative humidity of about 85%, except during dry season and sunshine of 5.1%. The soil samples were collected from different spots at a depth of 0-30 cm using a ziz-zag method and analysed at the Agronomy Laboratory of Osun State University, College of Agriculture. They were bulked together to form a composite soil sample for pre-planting soil analysis. The soil was air dried and sieved using 2 mm sieve, it was then analysed for both physical and chemical properties. Two organic treatments (rice bran, RB poultry manure, PM) and three different heights of prevailing wind movements (0 m, 1 m, and 2 m) were used in the research. The reason for using these 3 different heights of wind was because okra grows from 0 m height to between 1 and 2 m heights. Although some varieties may grow than 2 m, such variety was not popular in the Nigeria. Complementing this is the fact that vegetativeness was the focus of the research and not the okra seeds. The organic nutrient sources were applied to the field 30 days before seeds were sowed. These nutrients were allowed on the field for 30 days to synthesize naturally with the soil for its nutrients to be mineralized and become available and useful to the crops. Organic treatments were divided into eight: 5 tons/ha rice bran (RB5), 10 tons/ha of rice bran (RB10), 5 tons/ha poultry manure (PM5), 10 tons/ha poultry manure (PM10), 5 tons/ha each of rice bran and poultry manure (RB5PM5), 10 tons/ha rice bran and 5 tons/ha poultry manure (RB10PM5), 5 tons/ha rice bran and 10 tons/ha poultry manure (RB5PM10) and 10 tons/ha rice bran and 10 tons/ha poultry manure (RB10PM10). The okra variety, West African okra popularly called lady finger, was planted in May 2019 and vegetatively harvested in June 2019, a period of 42 days, (7 weeks). Spacing was 90 cm between the rows and 20 cm apart along the furrow, depth of planting was 1 inch deep.
There was a control experiment with zero organic amendment applied. The design was 3 × 2 × 6 factorial (3 different heights of winds from the ground surface, 2 organic amendments and 6 treatments). Each of these treatments was replicated three times, that is, 3 × 2 × 6 × 3 totaling 108. Temperature,

humidity, wind speeds and directions were taken at 10.00 h and 14.00 h daily using field digital thermometer (model SW-1189, made by Uniscope, Nigeria Ltd) to measure temperatures and using hygrometer model M50.60101, 023460 made in France to measure humidity. The values for wind parameters at different heights were collected from School meteorological unit. The temperature-humidity index (THI) values were computed. THI values results from combination of temperature and humidity as a degree of measure of comfort/discomfort experience by animal or crops were computed from temperature and humidity values using THI equation [14]:

$$THI = t_{db}-[0.31(1-\frac{RH}{100})(t_{db}-14.4)] \text{ in } ^oC$$

where:
THI = Temperature-Humidity Index
$t_{db}$ = dry bulb temperature, $^oC$
RH = relative humidity, %.

Moreover, other parameters measured were plant height using tape rule, number of leaves, and number of branches by direct counting of their number and stem girth was measured using vernier calipers. Also measured were vein length using tape rule and leaf area index. The leafy yields of okra were measured using standardized weighing scale.

The characteristics of the soil, the poultry manure and the rice bran used for the study are shown in Tables 1 and 2. The result of the chemical properties of the soil and their particle size analysis shows that the soil texture was sandy loam. Table 1 reveals that the soil is weakly acidic, this informs the low quantity (quality) of the cations in the soil and in its organic matter. With that low quantity of cations, there could be low cation exchange capacity of ions in the soil [18]. The bulk density value as shown is moderately good for the crop as well as the proportional quantity of soil particles in the soil. As shown in Table 1, the soil fertility was inherently low, based to the nutrients rating for soil fertility classes in Nigeria [15, 17] and this implies that cropping the soil without the use of soil amendments will affect the yield. However, organic carbon, nitrogen and the available P for poultry manure were higher than the corresponding values for soil, showing higher potential fertility inherent in it than the soil. Thus, it is capable of being used as amendment. Also, Table 2 reveals the proximate values from [21] for the rice bran, the higher ash content, 13.28 ± 0.26, could be able to add more nutrients to the soil which may adduced to the fact that the rice bran is not a bad choice to be used as soil amendment.

## Statistical Analysis

Table 1. Physico-chemical properties of the soil and poultry manure

| PARAMETERS | Soil | Poultry manure/100mg |
|---|---|---|
| Chemical properties | | |
| pH ($H_2O$) | 6.40 | 9.25 |
| Organic Carbon (%) | 0.52 | 6.76 |
| Total N (%) | 0.41 | 0.59 |
| Available P (mg/kg) | 16.7 | |
| $Na^+$(Cmol/kg) | 0.18 | 0.47 |
| $K^+$(Cmol/kg) | 1.22 | 0.55 |
| $Ca^{2+}$(Cmol/kg) | 1.22 | 0.31 |
| $Mg^{2+}$(Cmol/kg) | 0.69 | 0.33 |
| Organic matter (%) | | 11.49 |
| $Cu^{2+}$ | | 0.003 |
| $Fe^{2+}$ | | 0.57 |
| $Mn^{2+}$ | | 0.12 |
| $Zn^{2+}$ | | 0.03 |
| Bulk density (g/cm$^3$) | 1.2 | |
| Moisture content | | 75.44 |
| Particle size analysis | | |
| Silt (%) | 25.00 | |
| Clay (%) | 15.00 | |
| Sand (%) | 60.00 | |
| Textural Class | Sandy loam | |

Source: Primary data got from Laboratory analysis of soil and poultry samples', College of Agriculture, Osun State University, Nigeria.

Table 2. Chemical (Proximate) properties of rice bran

| Component (%) | Conventional rice bran |
|---|---|
| Moisture content | 9.99 ± 0.09 |
| Crude Protein | 11.01 ± 0.15 |
| Crude Fat | 15.17 ± 0.20 |
| Crude fibre | 16.47 ± 0.64 |
| Ash | 13.28 ± 0.26 |
| Carbonhydrate | 34.08 ± 1.22 |
| Reducing sugar | 6.13 ± 0.14 |

Source: [21].

The characters were subjected to analysis of variance using SPSS 16 and the means were separated using DMRT at 5% level of significance.

## RESULTS AND DISCUSSIONS

There was general increase in the number of leaves of okra during the formative weeks; this is expected as its foliage develops just like any other plant in that period [8]. However, there are differences in the level of foliage development as shown in Figure 1.

The general increase in the number of leaves of okra during the formative weeks are depicted in the differences within the level of foliage development, Figure 1, this could be from wind factors, which could have influenced other climatic factors or soil factors. In all, there were increase in vegetative growth, this further confirmed the report of [8] that nutrient's availability especially nitrogen determines plant vegetative grow.

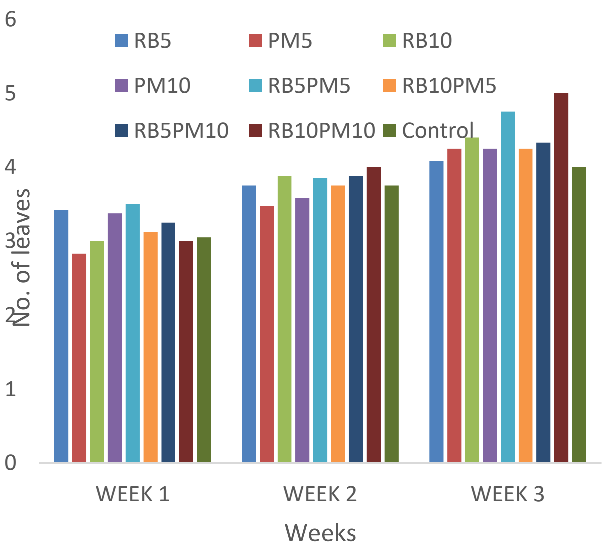


Fig.1. Average number of leaves during formative period of okra at different treatments
Source: Primary data gotten from field that was subjected to statistical analysis and latter expressed in Fig. 1.

Since some soil factors are the same for all the treatments, these differences depicted in the within the level of foliage development could be as a result of differences in the organic media contents in the treatments. Also, the differences could be as a result of differing wind speeds at different heights which could have led to variations in the temperature and humidity values recorded from the experimental field spots.

The temperature-humidity index, THI values as shown in Table 4 revealed varying values at different heights of wind from soil surface and weeks after planting (WAP) and growing. All the THI values were between the range 29.77 and 35.31 $^{o}$C. The temperature and humidity values where these THI values were computed from (using THI equation above), were within the acceptable range of 25 $^{o}$C-29 $^{o}$C and 67-80% respectively, they are within the range of the comfort zone for crops [14] in the tropics and therefore suitable for the okra.

There were statistical differences in the mean values for some yield components of okra namely plant height, leaf area index and in the stem girth shown in Table 3 among all the treatments and there are fluctuating weekly yield components' values as shown in Figures 1-2. This shows variations in the level of developments of each of the parameters as they contribute to the yield of the okra vegetatively. These results reveal evidence that the crops could have had interrupted comfortability during the period under consideration. Thus, their physiological processes could have been affected by the wind's speed or its prevailing direction in all the heights of wind's movements considered. This could have led to the resulted statistical differences in the mean values for some yield components of okra namely plant height, leaf area index and in the stem girth as shown in Table 3, although, the Least Significant Differences (LSD) values were low in both Table 3, this implying close mean values that were not too different.

The fluctuations recorded in weekly yield components' values in Figs. 1-2 could be surmised to have come from climatic factors namely winds' movements and possibly direction, temperatures and humidities and THI, just like how the heights of the wind movement to the ground surface could have resulted in different THI values, Table 3.

As a result of moderate THI values (30.00-34.74 $^{o}$C) in Table 4 and the wind movements as shown in their wind speeds' recorded (<10<50 km/h) at all different heights from the ground surface, Table 4, there were evident influences of all of these on okra. The highest LAI value in the RB5PM10 combination of rice bran and poultry manure in the mixing ratio 1:2 gave the highest vegetative stance (LAI = 397.50± 18.22 mm) for okra as shown in Table 3. This results also revealed that organic manure especially poultry manure could increase crops' height when combined with other source of manures. Thus proving that adding organic nutrients to the soil is good because it will act as a store house for cations with high exchangeable capacity and as a buffering agent against undesirable pH fluctuations [15]. This could be confirmed with the control experiment as it was observed that treatment without manure (control) did not do well compare to other treatments, even though, all of them were subjected to the same environmental conditions. The poor development of vegetative characters could happen if other factors like wind effects, and their resulting change in climatic factors near the crop's surface came as turbulence especially if the wind speeds are more than 50 km/h near the crops' surface [13].

Table 3. Mean characteristic performance of each treatment on Okra

| S/N | Treatments | Plant Height, cm | Leaf Area Index, $cm^2$ | Stem Girth, cm |
|---|---|---|---|---|
| 1 | Control | 18.50±10.20 bc | 270.00±12.22 c | 1.40±11.20 bc |
| 2 | RB5 | 19.13 ± 7.13 c | 323.50±11.12 b | 3.10 ± 8.32 a |
| 3 | RB10 | 20.78 ± 2.14 c | 326.21±21.23 b | 2.10 ± 2.20 b |
| 4 | PM5 | 22.00 ± 9.12 b | 336.93±12.11 b | 1.70 ± 11.82 c |
| 5 | PM10 | 24.13±3.10 ab | 354.18±21.20 ab | 1.80 ± 2.22 ab |
| 6 | RB5PM5 | 19.38 ± 2.16 c | 303.78± 22.01 bc | 1.70 ± 10.24 c |
| 7 | RB10PM5 | 22.63 ± 6.11 b | 311.59± 11.20 bc | 1.70 ± 8.20 c |
| 8 | RB5PM10 | 27.50 ± 8.15 a | 397.50± 18.22 a | 1.70 ± 6.25 c |
| 9 | RB10PM10 | 20.00 ± 2.10 c | 363.69.±12.02 ab | 2.00 ± 12.00 a |
| | LSD | 10.38 | 5.87 | 3.80 |

ab= Means in the same column followed by the same letter(s) are not significantly different at $p \leq 0.05$ by DMRT

Source: Primary data gotten from the field that was subjected to statistical analysis and latter expressed in Table 3.

RB5PM10 yielded tallest plant (27.50 ± 8.15 cm), though with low number of leaves (15.42 at week 7, Fig. 2) compare to RB10PM5, 16.42 and RB10PM10, 15.75, but also with maximum vegetative growth and leaf area (397.50 ± 18.22 $cm^2$) and stem girth 1.70 ± 6.25 cm, all at 1 m wind height. These translated to 48.64, 0.01, 47.22 and 21.43% more than their corresponding values in control experiment.

Table 4. THI (in degree centigrade) values at different heights of wind movement from the ground for all treatments

| Weeks | THI °C at different heights of wind movements from the ground surface | | |
|---|---|---|---|
| | 0 m | 1 m | 2 m |
| 1 | 34.42 | 34.44 | 34.74 |
| 2 | 35.31 | 33.56 | 33.10 |
| 3 | 31.31 | 32.07 | 32.85 |
| 4 | 30.44 | 29.77 | 30.92 |
| 5 | 31.61 | 31.03 | 30.75 |
| 6 | 30.80 | 30.97 | 31.79 |
| 7 | 32.04 | 31.17 | 31.33 |

Source: Primary data gotten from the field that was subjected to statistical analysis and latter expressed in Table 4.

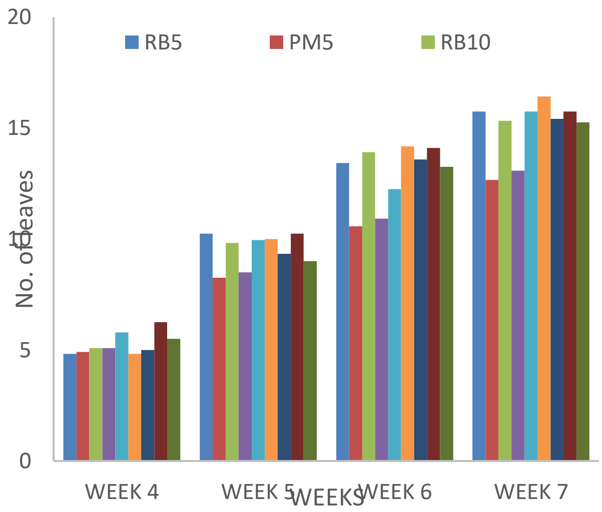


Fig. 2. Average number of leaves during maturing period of okra at different treatments

Source: Primary data gotten from the field that was subjected to statistical analysis and latter expressed in Fig. 2.

There were linear increases in growth parameters and yield components from 0 m to 1 m and to 2 m wind heights, Figure 2. All these could be the reason why combination of rice bran and poultry manure gave the highest vegetative stance for okra as in the increase in number of leaves per plant and plant stem girth with organic fertilizer application. This stresses the importance of adding organic media during the vegetative growth of plants.

The computed THI values from air temperature and humidity are shown in Table 4. The wind speeds were lower than 50 km/h. These values of wind speed were always at EW direction in more than 75% of the days/times when they were measured. From Table 5, the standard deviation values are very low depicting that the wind speed values are close in values (LSD also attests to this), thus the wind movement within the period was moderately low and apparently uniform. There were also statistical differences among the wind speed values signifying differences as a result of the heights of the wind from the ground at the time 10.00h and 14.00h during measurements.

Table 5. Weekly mean values of wind speed at 0, 1 and 2 m wind's height

| Weeks | Wind speed at different heights from ground surface, km/h | | |
|---|---|---|---|
| | 0 m | 1 m | 2 m |
| 1 | 6.02 ± 2.12c | 6.21 ± 1.62c | 7.07 ±1.00c |
| 2 | 7.02 ± 1.19a | 6.82 ± 2.00c | 8.66 ±2.24a |
| 3 | 6.73 ± 2.04ab | 8.10 ± 1.01a | 7.42 ±2.70b |
| 4 | 6.21 ± 1.58b | 8.09 ± 1.60a | 7.30 ±1.47b |
| 5 | 6.11 ± 1.07b | 7.00 ± 2.00ab | 8.00 ±1.86ab |
| 6 | 6.22 ± 1.21b | 6.87 ± 2.13c | 7.09 ±1.72c |
| 7 | 7.31 ± 1.75a | 8.77 ±1.43a | 7.10 ±1.07c |
| LSD | 5.22 | 6.34 | 8.77 |

Note: Wind direction = EW

Source: Primary data gotten from the field that was subjected to statistical analysis and latter expressed in Table 5.

These differences could be the same reason why yield parameters in Table 3 were statistically different. The Least Significant Differences (LSD) values were low in both Table 5 implying close mean values that were not too different and infer that the difference between the wind speeds at various levels tested were significant.

Although the okra planted were not wind-induced, yet wind directly affects their growth rates and hence leafy yields and therefore could have resulted into statistical differences among the yield components of okra. Also, moderate wind resulted from combined effects from THI values in Table 4 could have directly affected okra's growth rates and hence leafy yields in the sense that wind's carrying lower THI values as depicted in computed THI in Table 4 were warm, (maximum THI = 34.74). since warm air does not cause turbulence but calmness, then this could further be explained as resulting calm to moderate wind. This favours dew deposition needed under condition of soil moisture stress and could have helped the plants to grow positively [1].

This is evidence from Table 5, the low standard deviation values depict that the wind speed values although not too different but infer that the wind movement within the period was moderately low, apparently uniform and non- turbulent, although, there was turbulent mixing, but it was of normal and balance mixing that are apparently tolerable to crops' comfort [3, 16], because the crops were still able to do well (Table 3). Also, at different heights from the ground surface, the wind speeds as shown are differently lower in values for each of the height, this that the winds was not turbulent throughout and could have been responsible for the low THI computed from low temperatures and humidity values, Table 4- these low THI values are positive to induce good leafy growth in the okra [12, 14]. Furthermore, it was because the wind speeds were low than 50 km/h, which if it was more could have caused lodging of okra plant and dilapidated leaves from the wind turbulence [12, 13]. And since this was not so, due to the low values of the wind speed, the crops could be adjudged to be comfortable at those temperatures, humidities and the THI(s) since there were no stalking nor lodging of okra plant and dilapidated leaves.

Then with the reduction in wind, less turbulent mixing could have occurred near the okra leaves' surfaces. Turbulent mixing is the process which happens during the day when warm air from the surface rises and is replaced by the cooler air aloft [16, 22] and since this occurred moderately on the crop surface (as evident in the non-stalking, non-lodging okra leaves), injury were not caused to the okra leaves. This was evident in the leaves that were neither broken nor dilapidated during the experiment. Based on above therefore, it could be adjudged that the wind speed, as it was, reduced near the okra leaves at 1 m, this could signify the quiet/calm zone near the okra leaves. The effect of reducing the amount of turbulent mixing involved will allow air temperatures near the surface to decrease and this decrease reflected in the computation of the THI values (Table 4). But this increase was not significant enough to cause problem. In contrast, this increase could possibly hasten the development of a crop as observed by [22] in their experiment in the desert region of Nigeria. It could also be that because of the reduced turbulence mixing in air on the okra leaves surfaces that made the number of leaves more favourable in the experiment as shown in Figures 1 - 2. This can be surmised to be so because the reduced amount of wind and turbulent mixing in the quiet/calm zone could have produced an effect on crop temperatures and then the yield [16, 13]. This is also because reduction in wind speed reduces the amount of evaporation from leaves' surfaces, the manure applied could have served as source of moisture for the okra to compensate for possible reduced evaporation by scorching sun. The implication of the findings is that lowering of temperature-humidity index values at the surfaces of the okra leaves which can be achieved through orientation of crop to the prevailing wind and keeping the crop at predetermined height of growth will help the growth and yield of okra. This is because the 1 m wind's height level allows low turbulent air mixing on the crop's surface which was good for crops. Wind movements especially when it has turbulent mixing in the quiet zone will produce effect on crops' ambient temperatures and THI and then on the leafy yield of okra. Also, it could have helped in the improvement in the performances of the crop as there could have been reduced evapo-transpiration from the okra and thus resulted comfortability that will lead to their good growth. Thus the consequences that vegetative yield will increase and provide more income for the farmers and enhancing positively our food security.

## CONCLUSIONS

Application of rice bran and poultry manure in ratio 1:2 in the soil enhanced all the yield components of okra such as plant height, number of plant leaves, number of branches per plant and stem girth. Different organic treatments for okra affect its performances via growth parameters when the wind's speed was at 1 m height. Okra will do well vegetatively when wind speed is less than 50 km/h in any good soil of good moisture to cater for reduced evaporative cooling on its leaves.

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# STUDIES ON THE INFLUENCE OF THE LEVEL OF FINANCIAL SUPPORT ON THE TREND OF AREA CULTIVATED IN ORGANIC FARMING SYSTEM

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***Abstract***

*Organic farming promotes extensive agricultural practices, providing environmental public goods and responding to society's demand for the use of environmentally friendly agricultural practices, but also to increased consumer demand for organic products. Organic agriculture contributes to mitigating the greenhouse effect and global warming, through the ability to sequester carbon in the soil. Many practices used in organic agriculture (for example, incorporation of plant residues into the soil, use of green crops and crop rotation, the ability of vegetables and legumes to fix nitrogen in the soil), increase the return of carbon to the soil, increase productivity and promote carbon storage. Organic agriculture is a dynamic sector in Romania that has seen an upward evolution in recent years. Through the study carried out, we aimed to highlight the evolution of agriculture in an ecological system with the help of compensatory payments granted by the European Union, in the South - West Oltenia Region of Romania, in the period 2019 - 2021. It was found that the surface of 18,420 hectares in 2019 increased to 36,241 hectares in 2021, and until 2024 it is expected that the trend of the area cultivated in the ecological system also to grow.*

***Key words***: *organic farming, compensatory payments, sustainable agriculture, agricultural policy*

## INTRODUCTION

The practices specific to ecological agriculture contribute to protecting biodiversity, maintaining soil fertility and functionality, reducing water resource pollution (by eliminating pesticide runoff, strict manure management) and improving water management (improving soil structure, reducing the risk and severity of floods and drought, in the context of climate change), reducing carbon dioxide emissions and ensuring animal welfare conditions (reduced livestock density). In addition to their environmental benefits, they can serve as a basis for increasing the added value of agricultural production and developing economic activities at the local level [5].

One of the future options is ecological agriculture, which emphasizes sustainability, human health, biological conservation and combines scientific knowledge and modern technology with traditional agricultural practices based on thousands of years of agriculture [3]. In our country, ecological agriculture represents a sector of interest, being one of the main segments of sustainable development in the rural environment. Ecological agriculture can lead to: maintaining fertility, increasing biological diversity for plants and animals, recycling residues from agricultural production, obtaining clean products, reducing environmental pollution, protecting health, creating friendly relations between productive activities and environmental conservation [11]. The transition to organic farming is becoming a necessity in a sustainable development society. Based on the circumstances predetermining Romania's potential to develop organic agriculture, the challenge of convergence in organic agriculture remains a relevant issue for Romania in the medium and long term [8].

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Ecological agriculture is a sector of great perspective for Romania, due to the fact that it enjoys suitable conditions for the development of such an agricultural system, fertile soils and low level of pollution of the rural landscape, compared to economically developed countries, where technologies are used large-scale super-intensive agriculture, based largely on chemical fertilizers and pesticides [9]. The European Union's Common Agricultural Policy (CAP) has not stopped the loss of farmland biodiversity. The post-2023 CAP has a new "Green Architecture", including the new "Eco-scheme" tool [7]. Environmental and climate expectations are likely to increase in the next EU Common Agricultural Policy cycle; therefore, the topic of agriculture for soil conservation is justified to be a priority and requires preparation for the development of appropriate interventions in the National CAP Strategic Plan [2]. European agriculture, and implicitly that of Romania, must respond to a new challenge, that of reducing the amounts of pesticides used, according to the demands of the Farm to Fork strategy, a component of the Green Deal, which requires that 25% of the agricultural area be dedicated to ecological agriculture and a 50% reduction in the use of pesticides, an aspect we will detail in this scientific communication [4]. The concept of sustainable development appeared in an attempt to reconcile agri-food production with measures to conserve non-renewable resources, but also an attempt to protect the environment, and in this process the farmer has an important role considering the effects that specific activities have. so much on the environment. Because of this, more and more actors involved in this process, from farmers to consumers, but also politicians have begun to pay more attention to ecological agriculture, as an advantageous means of reconciliation between man and nature [10].

In PNDR 2014-2020, Measure 11 - "Organic agriculture" seeks to encourage the conversion to ecological agriculture methods, as well as the maintenance of these methods after the end of the conversion period. The budget for this new measure in Romania is 36.1 million euros, including both European funds and the national contribution, according to data published by the Ministry of Agriculture, which are informative. The selection criteria and the amounts that the beneficiaries will receive will be established after the European Commission approves the new PNDR 2020. The support is given to farmers as a fixed amount per surface unit (ha) and represents compensation for the loss of income and the additional costs incurred by beneficiaries who enter into commitments regarding the conversion or maintenance of organic farming practices [6].

## MATERIALS AND METHODS

The purpose of this study is to analyze the impact of environmental and climate measures that are applied through the new agricultural policies and strategies in the context of climate change, in Romania, through the National Rural Development Program, in the period 2019-2021.

The situation of payment requests was extracted from the database of the general monitoring of the Agency for Payments and Intervention in Agriculture.

All payment requests were analyzed regarding the number of beneficiaries, the related areas, as well as their payment amount. A detailed analysis was carried out on the specific measure M11 – Organic Farming. A statistical analysis of the data was carried out regarding the forecasts of cultivated areas related to Measure M11, in the period 2022-2024, in the South-West Oltenia Region, applying the formula below:

$$Y(x) = y(1) + \frac{x-x(1)}{x(2)-x(1)} * [y(2) - y(1)] \qquad (1)$$

where:

•[x(1), y(1)] and [x(2), y(2)] are two endpoints of the known interval;

• x - the value of the point to be extrapolated.

To highlight the influence between the cultivated area related to Measure M11 (Organic Agriculture) and the total area declared APIA, the following formulas are used:

-The correlation coefficient:

$$r = \frac{\Sigma(x_i-\overline{X})(y_i-\overline{Y})}{\sqrt{\left(\Sigma(x_i-\overline{X})^2\right)\left(\Sigma(y_i-\overline{Y})^2\right)}} \quad (2)$$

where:

x and y are the means for the samples, AVERAGE (array 1) and AVERAGE (array 2)

-Linear and polynomial function of the second degree:

Linear – linear model (simple regression):

$$y = a + bx \quad (3)$$

Polynomial function:

$$y = a_0 + a_1x^1 + a_2x^2 + \ldots + a_nx^n \quad (4)$$

## RESULTS AND DISCUSSIONS

In Table 1, it is noted that the number of hectares declared at APIA, in the South-West Oltenia Region, increased every year, in the analyzed period 2019 - 2021. In 2019, a total of 1,005,050 hectares were declared, being represented by 105,245 payment requests. In 2020, the surface increased to 1,031,657, and the number of financing applications increased by 121,638. In the last analyzed year, the area registered at APIA increased to the value of 1,054,436 hectares, and the number of applications increased to 120,456. It is noted that the number of applications, as well as the number of hectares, were constantly increasing.

Table 1. The situation of APIA payment requests in the South - West Oltenia Region

| County | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|
| | **No. Payment requests** | **Ha** | **No. Payment requests** | **Ha** | **No. Payment requests** | **Ha** |
| **Dolj** | 27,011 | 413,595.80 | 34,650 | 421,814.02 | 34,618 | 426,840.02 |
| **Gorj** | 16,109 | 65,763.00 | 17,693 | 69,890.50 | 17,238 | 70,934.14 |
| **Mehedinți** | 18,721 | 132,870.00 | 21,193 | 138,954.49 | 21,226 | 145,228.98 |
| **Olt** | 26,082 | 330,711.02 | 29,129 | 332,804.15 | 28,995 | 340,377.40 |
| **Vâlcea** | 17,322 | 62,110.58 | 18,973 | 68,194.09 | 18,379 | 71,055.51 |
| **Total** | **105,245** | **1,005,050** | **121,638** | **1,031,657** | **120,456** | **1,054,436** |

Source: Own calculation based on APIA data [1].

Table 2. Cultivated area related to Measure M11 – Organic Agriculture

| Year | County (ha) | | | | | Total Oltenia (ha) | Value (euro) |
|---|---|---|---|---|---|---|---|
| | **Dolj** | **Gorj** | **Mehedinți** | **Olt** | **Vâlcea** | | |
| **2019** | 2,670.64 | 10,369.97 | 1,697.83 | 2,164.06 | 1,517.74 | **18,420** | **1,948,706** |
| **2020** | 4,564.05 | 11,759.05 | 2,281.96 | 3,837.75 | 3,263.11 | **25,706** | **3,100,914** |
| **2021** | 7,186.96 | 14,301.74 | 2,542.96 | 6,731.75 | 5,477.93 | **36,241** | **4,740,233** |
| **Total** | **14,421.65** | **36,430.76** | **6,522.75** | **12,733.56** | **10,258.78** | **80,367.50** | **9,789,853** |

Source: Own calculation based on APIA data [1].

Table 2 shows that in the South - West Oltenia Region, during the analyzed period, 2019 - 2021, the declared area belonging to Measure 11 - Ecological Agriculture increased, in 2019 the declared area was 18,420 hectares (1,948,706 euros), in In 2020 the declared area increased to 25,706 hectares (3,100,914 euros), and in 2021 it increased to 36,241 hectares (4,740,233 euros).

Regarding the forecasts regarding the cultivated areas related to Measure M11 – Organic Farming, it is observed that at the level of the South - West Olteniea Region, it is expected that the areas declared with this

Measure, in the following years, 2022 - 2024, will increase in the counties of this area (Figure 1).

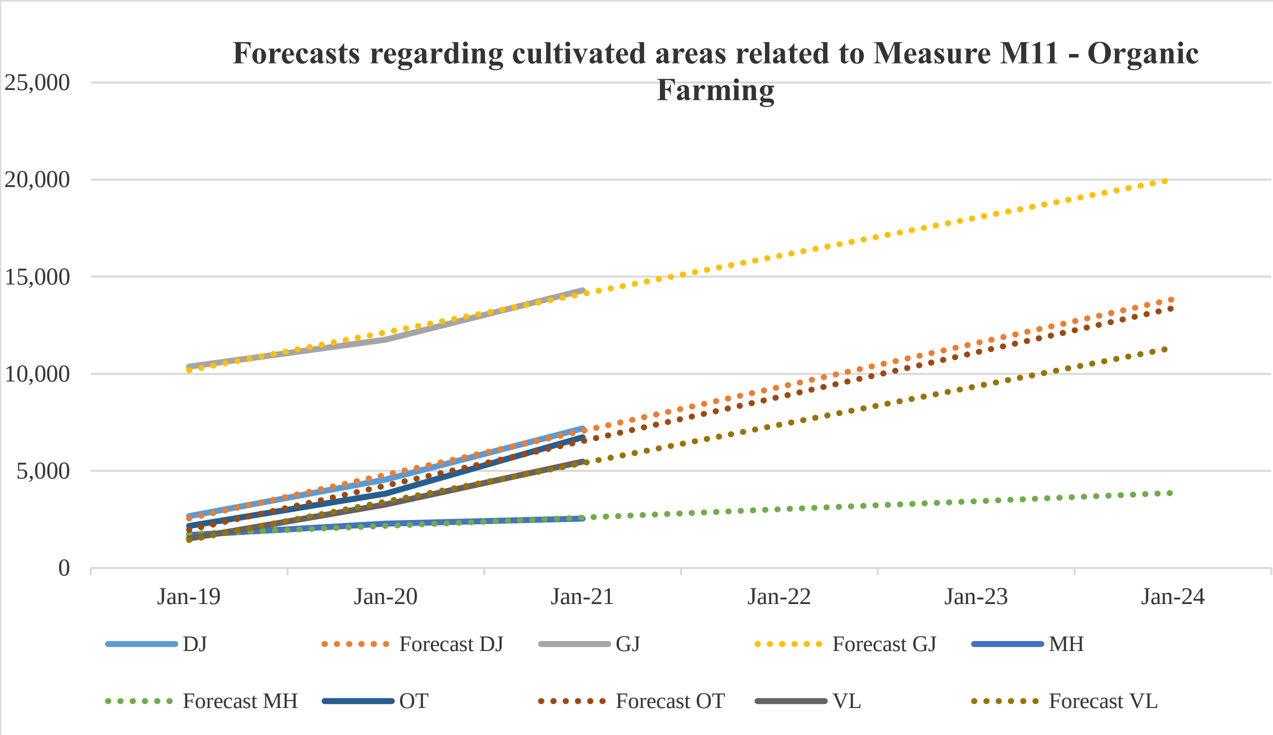


Fig. 1. Forecasts regarding cultivated areas related to Measure M11 – Organic Farming, 2022-2024
Source: Own construction.

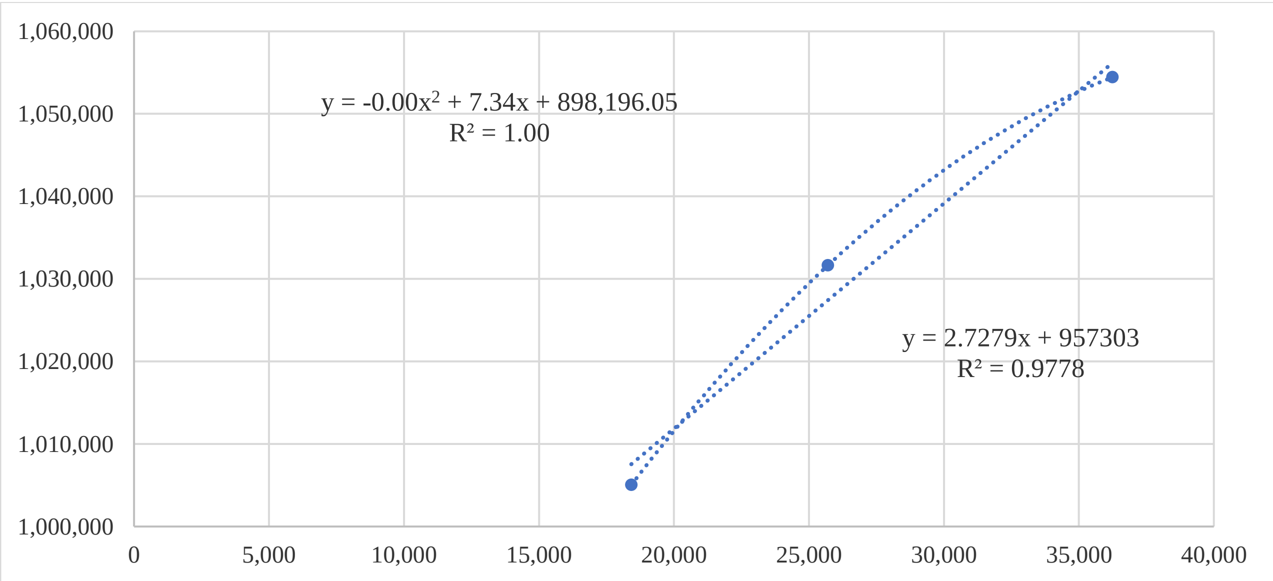


Fig. 2. Correlation between the area related to measure M11 and the total area declared at APIA in the South - West Oltenia Region (2019 - 2021)
Source: Own construction.

The correlation of the values between the area related to measure M11 and the total area declared at APIA in the South - West Oltenia Region, resulted in a strong direct correlation (r=0.98). This is due to the fact that in this analyzed period, 2019 – 2021, both values of the analyzed surfaces have increased. Also, the value of the polynomial function of the second degree ( y = -0.00x2 + 7.34x + 898,196.05) R2=1 indicates the same thing (Figure 2).

## CONCLUSIONS

The situation of payment requests registered at the Agency for Payments and Intervention in Agriculture, in the Southwest Oltenia Development Region, between 2019 and 2021, was increasing, where in 2019 105,245 payment requests were registered with 1,005,050 hectares, and in 2021, 120,456 payment requests were registered with 1,054,436 hectares.

The cultivated areas related to Measure M11 – Organic Farming, in the Southwest Oltenia Development Region, in the period 2019 - 2021, increased from the surface of 18,420 hectares in 2019, to the value of 36,241 hectares in 2021. During this entire analyzed period, 2019 – 2021, Gorj County has the largest area registered in the ecological system with 36,430.76 hectares, and Mehedinti County has the smallest area registered in the ecological system with 6,522.75 hectares. Regarding the interest in this measure, according to the forecasts for the years 2022 - 2024, it is estimated that it will increase in the following years, in the counties of the South West Oltenia region.

The increased interest for Measure 11, and from the direct correlation between the area related to Measure 11 and the total area declared at APIA, as the total areas declared at APIA increase, the areas cultivated in the ecological system also increase (correlation coefficient = 0.98).

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# STUDIES ON THE LEVEL OF 'AGRO-ENVIRONMENT AND CLIMATE' COMPENSATORY PAYMENTS GIVEN TO ROMANIAN FARMERS

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***Abstract***

*Agri-environment and climate payments represent a key element necessary for the integration of environmental protection issues into the Common Agricultural Policy. In Romania, this measure aims to encourage farmers (users of agricultural land) to adopt, on a voluntary basis, agricultural practices that ensure the maintenance of the environmental value of rural areas, the maintenance of specific habitats of agricultural land important for priority wild species, the sustainable use of natural resources and the preservation of traditional landscapes. This paper presents the situation of accessing the agri-environment and climate compensatory payment measure for adaptation to the effects of climate change on agricultural land, in Romania, between 2015 and 2019, where a total of 212,413 beneficiaries were registered, with a total eligible area of 1,799,820 hectares and the eligible value of compensatory payments was 231,563,125.73 euros.*

***Key words*****:** *climate change, payments, agro-environment, common agricultural policy, sustainable agriculture, sustainable development, biodiversity*

## INTRODUCTION

Agri-environment payments are necessary to support the sustainable development of rural areas and to meet society's increasing demand for environmental services. The payments granted by this measure must encourage farmers to serve society as a whole by introducing or continuing the application of agricultural methods compatible with the protection and improvement of the environment, the landscape and its characteristics, natural resources, the soil, as well as with the maintenance of genetic diversity [8].

The promotion of traditional, extensive agricultural practices, based on a reduced use of inputs, is necessary to support the sustainable development of rural areas, contributing to the conservation of biodiversity (wild species and their habitats, local animal breeds), soil and water protection, reducing emissions of greenhouse gases and ammonia, carbon sequestration in biomass, reducing the risk of intensification, but also to a sustainable management of natural resources [12].

In December 2019, the European Commission issued a communication on the European Green Deal strategy, which was to launch new international actions to achieve ambitious climate and environmental goals [13].

Farmers are aware of the problems caused by the effects of climate change and are willing to adapt by implementing the necessary solutions [6].

The regions with the highest share in the consumption of mineral fertilizers in Romania, in descending order, are: West, South Muntenia, South West Oltenia, North East, South East and North West regions, and agro-environment and climate measures would be a potential solution to reduce the consumption of these substances [9], as well as the reduction of polluting substances in agriculture [5].

Research has examined the impact of green payment programs on agricultural and economic outcomes such as agricultural productivity and farm income, improving their yield [4].

Agriculture is a sector of the economy that depends a lot on the climate. The final impact of climate change on agriculture depends on the resilience of ecosystems, as well as on the measures taken by the authorities, collectively and individually. Also, the natural resistance of ecosystems influences the effect of climate change on them [2].

EU farmers are subject to mandatory cross-compliance measures, which require them to meet environmental conditions to be eligible for public support. These obligations strengthen the incentives for farmers to change their behavior towards the environment [3].

Policymakers aiming to reduce pollution from agriculture should consider the increasing use of precision agriculture techniques and their varying effects on agri-environmental policy [11].

The value of agricultural production increases through better management of farms and through the financial support granted according to the PAC of the EU and the Romanian Government [10].

## MATERIALS AND METHODS

The European Ecological Pact (Green Deal) which is part of the new Common Agricultural Policy, respects the requirements of the European Commission, which aim to tighten the conditions for climate and environmental objectives, respectively maintaining continuity for sustainable development and ensuring the continuity of environmental protection. Adapting to the effects of climate change on agricultural land by reducing greenhouse gas emissions, as well as the efficient and sustainable management of natural resources such as air, water and soil, as well as the preservation of biodiversity, landscapes, habitats, all of these ensure sustainable development.

The purpose of this work is to present the situation of access to Measure 10 – Agroenvironment and Climate in Romania [7], in the period 2015 – 2019.

The data were extracted from the database of the Payments and Intervention Agency and processed as follows: the number of beneficiaries, the areas and the value eligible for package 1 - meadows with high natural value, package 4 - green crops and package 8 - raising farm animals from local breeds in danger of abandonment.

## RESULTS AND DISCUSSIONS

It is highlighted that at the beginning of this study, i.e. in 2015, the smallest area was declared for these compensatory payments related to package 1, namely 151,802 hectares, with a total of 17,621 beneficiaries, and the total compensatory value paid was 12,996,017.75 euros. The farmers who applied for package 1 were very many in 2016, there were a total of 32,307 beneficiaries, which represented a total eligible area of 254,121 hectares, where the total value of compensatory payments was 23,777,005.39 euros. Also, in the following year, 2017, the number of beneficiaries who applied for measure 1 increased, reaching 42,713, with a total eligible area of 345,421 hectares, and the value of compensatory payments for this year was 48,572,464.67 euros. The increase in the area declared with package 1 was also maintained in 2018, where 500,472 hectares were declared, with a number of 57,845 beneficiaries, and the value of compensatory payments for this package was 69,698,330.89 euros. The number of farmers who benefited from compensatory payments through package 1 of Measure 10 – Agro-environment and Climate, increased constantly, until 2019, where 61,927 farmers were registered, with a total area of 548,004 hectares, and their total value was 76,519,307.03 euros (Table 1).

Table 1 shows that in the period 2015 - 2019, in Romania, the value of the compensatory payments of package 1 (high natural value meadows) from Measure 10 - Agroenvironment and Climate of the 2014 - 2020 PNDR, were 231,563,125.73 euros, with a total number of beneficiaries of 212,413 and a total area of 1,799,820 hectares.

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Table 1. The situation of accessing package 1 of measure 10, in the period 2015 – 2019, in Romania

| *Year* | *No. beneficiaries* | *Area (ha)* | *Value (euro)* |
|---|---|---|---|
| ***2015*** | 17,621 | 151,802 | 12,996,017.75 |
| ***2016*** | 32,307 | 254,121 | 23,777,005.39 |
| ***2017*** | 42,713 | 345,421 | 48,572,464.67 |
| ***2018*** | 57,845 | 500,472 | 69,698,330.89 |
| ***2019*** | 61,927 | 548,004 | 76,519,307.03 |
| ***Total*** | **212,413** | **1,799,820** | **231,563,125.73** |

Source: Own calculation based on APIA data [1].

Table 2. Value of the budget allocated to package 1 of measure 10 and the percentage of absorption, in the period 2015 – 2019, in Romania

| *Year* | *Specification* | *Value (euro)* | | *% absorption* |
|---|---|---|---|---|
| | | **EAFRD** | **National Value** | |
| ***2015*** | **Total** | 12,338,957.71 | 657,060.04 | 91.82 |
| | | 12,996,017.75 | | |
| | **EU budget** | 14,154,169.41 | | |
| ***2016*** | **Total** | 22,194,075.11 | 1,582,930.28 | 94.63 |
| | | 23,777,005.39 | | |
| | **EU budget** | 25,124,988.81 | | |
| ***2017*** | **Total** | 40,596,426.99 | 7,976,037.68 | 96.68 |
| | | 48,572,464.67 | | |
| | **EU budget** | 50,241,382.10 | | |
| ***2018*** | **Total** | 58,163,246.50 | 11,535,084.39 | 98.10 |
| | | 69,698,330.89 | | |
| | **EU budget** | 71,046,664.22 | | |
| ***2019*** | **Total** | 63,855,350.12 | 12,663,956.91 | 98.33 |
| | | 76,519,307.03 | | |
| | **EU budget** | 77,816,545.28 | | |
| ***Total value of compensatory payments*** | | 231,563,125.73 | | 97.14 |
| ***Total EU budget*** | | 238,383,749.82 | | |

Source: Own calculation based on APIA data [1].

Table 3. The situation of accessing package 4 of measure 10, in the period 2015–2019, in Romania

| *Year* | *Beneficiary* | *Area* | *Value (euro)* |
|---|---|---|---|
| ***2015*** | 590 | 30,690.04 | 3,837,218.78 |
| ***2016*** | 961 | 46,504.29 | 5,655,716.77 |
| ***2017*** | 1,735 | 81,707.25 | 10,364,987.79 |
| ***2018*** | 2,099 | 114,305.40 | 13,433,440.20 |
| ***2019*** | 2,121 | 125,822.81 | 15,684,111.29 |
| ***Total*** | **7,506** | **399,030** | **48,975,474.83** |

Source: Own calculation based on APIA data [1].

Table 2 shows that in the period 2015 - 2019, in Romania, the value of the compensatory payments of package 1 (high natural value meadows) from Measure 10 - Agroenvironment and Climate of the 2014 - 2020 PNDR, were 231,563,125.73 euros, which represents a absorption percentage of 97.14% of the total EU budget, from this period, with a value of 238,282,749.82 euros. The evolution of the budget allocated by the European Union for package 1 (meadows with high natural value) was increasing throughout the analysis period, reaching from 14,154,169.41 euros, in 2015, to the value of 77,816,545.28 euros in 2019. Also, the percentage of absorption from the total budget allocated by the EU, of compensatory payments, was continuously increasing, from the value of 91.82% in 2015, to the value of 98.33% in 2019 (Table 2). Table 3 shows that in the period 2015 - 2019, in Romania, the value of the compensatory payments of package 4 (green crops) from Measure 10 - Agroenvironment and Climate from National Programme of Rural Development (PNDR) 2014 - 2020, were 48,975,474.83 euros, with a total number of beneficiaries of 7,506 and a total area of 399,030 hectares.

It is highlighted that at the beginning of this study, i.e. in 2015, the smallest area was

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declared for these compensatory payments related to package 4, namely 30,690.04 hectares, with a total of 590 beneficiaries, and the total compensatory value paid was 3,837,218.78 euros. Package 4 met a special interest from farmers, where in 2016 961 beneficiaries applied, representing a total eligible area of 46,504.29 hectares, and the total value of compensatory payments was 5,655,716.77 euros. There was the same interest for this package in the following year, 2017, where there were a total of 1,735 beneficiaries, with a total eligible area of 81,707.25 hectares, where the total value of compensatory payments for this package was 10,364,987.79 euros. The year 2018 had the largest area recorded with package 4, where there were a total of 114,305.40 hectares, representing a number of 2,099 beneficiaries, and the value of compensatory payments was 13,433,440.20 euros. The number of farmers who benefited from compensatory payments through package 4 of Measure 10 – Agro-environment and Climate, increased constantly, until 2019, where 2,121 farmers were registered, with a total area of 125,822.81 hectares, and their total value was 15,684,111.29 euros (Table 3).

Table 4. Value of the budget allocated to package 4 of measure 10 and the percentage of absorption, in the period 2015 – 2019, in Romania

| *Year* | *Specification* | *Value* | | *% absorption* |
|---|---|---|---|---|
| | | **EAFRD** | **National Value** | |
| ***2015*** | **Total** | 3,644,916.69 | 192,302.09 | **91.60** |
| | | **3,837,218.78** | | |
| | **EU budget** | **4,189,246.00** | | |
| ***2016*** | **Total** | 5,117,006.10 | 538,710.67 | **84.23** |
| | | **5,655,716.77** | | |
| | EU budget | **6,714,969.60** | | |
| ***2017*** | **Total** | 8,662,913.38 | 1,702,074.41 | **97.30** |
| | | **10,364,987.79** | | |
| | **EU budget** | **10,652,797.44** | | |
| ***2018*** | **Total** | 11,209,032.97 | 2,224,407.23 | **93.72** |
| | | **13,433,440.20** | | |
| | **EU budget** | **14,333,172.39** | | |
| ***2019*** | **Total** | 13,083,454.28 | 2,600,657.01 | **97.38** |
| | | **15,684,111.29** | | |
| | **EU budget** | **16,105,319.68** | | |
| ***Total value of compensatory payments*** | | **48,975,474.83** | | **94.19** |
| ***Total EU budget*** | | **51,995,505.11** | | |

Source: Own calculation based on APIA data [1].

Table 4 shows that in the period 2015 - 2019, in Romania, the value of the compensatory payments of package 4 (green crops) from Measure 10 - Agroenvironment and Climate of the 2014 - 2020 PNDR [13], were 48,975,474.83 euros, which represents a percentage of absorption of 94.19% of the total EU budget, from this period, with a value of 51,995,505.11 euros.

The evolution of the budget allocated by the European Union for package 4 (green crops) was increasing throughout the analysis period, reaching from 4,189,246.00 euros, in 2015, to the value of 16,105,319.68 euros in 2019. Also, the percentage of absorption from the total allocated budget of the EU, of compensatory payments was continuously increasing, from the value of 91.60% in 2015, to the value of 97.38% in 2019 (Table 4).

Table 5 shows that in the period 2015 - 2019, in Romania, the value of the compensatory payments of package 8 (breeding of farm animals from local breeds at risk of abandonment) from Measure 10 - Agro-environment and Climate from PNDR 2014 - 2020 [13], were 801,361.18 euros, which represents an absorption percentage of 70.14% of the total EU budget, from this period, with a value of 1,142,476.22 euros. The total values of the compensatory payments for each species are 17,150.22 euros for goats, 470,194.00 euros for sheep, 96,161.00 euros for cattle, 154,162.36 euros for pigs and 63,693.60 euros for equids.

Table 5. Value of the budget allocated to package 4 of measure 10 and the percentage of absorption, in the period 2015 – 2019, in Romania

| *Year* | *Specification* | *Value (euro)* | | | | | | | | | | *% absorption* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Goats** | | **Sheep** | | **Cattle** | | **Suines** | | **Horses** | | |
| | | **FEADR** | **BN** | **FEADR** | **BN** | **FEADR** | **BN** | **FEADR** | **BN** | **FEADR** | **BN** | |
| ***2015*** | **Total every species** | 401.18 | 78.82 | 39,170.12 | 3,693.57 | 17,653.17 | 3,177.83 | 3,392.12 | 558.20 | 8,470.00 | 623.60 | **44.18** |
| | | 480.00 | | 42,863.69 | | 20,831.00 | | 3,950.32 | | 9,093.60 | | |
| | **Total Package 8** | **77,218.61** | | | | | | | | | | |
| | **EU budget** | **174,798.35** | | | | | | | | | | |
| ***2016*** | **Total every species** | 3,188.92 | 626.48 | 71,457.56 | 12,476.95 | 8,227.53 | 1,592.47 | 5,937.68 | 982.64 | 9,760.38 | 1,055.62 | **57.17** |
| | | 3,815.40 | | 83,934.51 | | 9,820.00 | | 6,920.32 | | 10,816.00 | | |
| | **Total Package 8** | **115,306.23** | | | | | | | | | | |
| | **EU budget** | **201,694.40** | | | | | | | | | | |
| ***2017*** | **Total every species** | 3,276.46 | 643.76 | 98,723.72 | 19,398.05 | 19,056.24 | 3,743.76 | 26,057.42 | 5,119.22 | 9,528.12 | 1,871.88 | **76.09** |
| | | 3,920.22 | | 118,121.77 | | 22,800.00 | | 31,176.64 | | 11,400.00 | | |
| | **Total Package 8** | **187,418.63** | | | | | | | | | | |
| | **EU budget** | **246,324.34** | | | | | | | | | | |
| ***2018*** | **Total every species** | 3,477.36 | 689.64 | 99,821.67 | 19,796.87 | 15,521.70 | 3,078.30 | 41,540.56 | 8,238.40 | 13,168.41 | 2,611.59 | **74.43** |
| | | 4,167.00 | | 119,618.54 | | 18,600.00 | | 49,778.96 | | 15,780.00 | | |
| | **Total Package 8** | **207,944.50** | | | | | | | | | | |
| | **EU budget** | **279,364.83** | | | | | | | | | | |
| ***2019*** | **Total every species** | 3,978.57 | 789.03 | 88,169.52 | 17,485.97 | 20,119.81 | 3,990.19 | 52,019.48 | 10,316.64 | 13,856.04 | 2,747.96 | **88.84** |
| | | 4,767.60 | | 105,655.49 | | 24,110.00 | | 62,336.12 | | 16,604.00 | | |
| | **Total Package 8** | **213,473.21** | | | | | | | | | | |
| | **EU budget** | **240,294.30** | | | | | | | | | | |
| ***Total every species*** | | **17,150.22** | | **470,194.00** | | **96,161.00** | | **154,162.36** | | **63,693.60** | | **70.14** |
| ***Total Package 8*** | | **801,361.18** | | | | | | | | | | |
| ***Total EU budget*** | | **1,142,476.22** | | | | | | | | | | |

Source: Own calculation based on APIA data [1].

The evolution of the budget allocated by the European Union for package 8 (breeding of farm animals from local breeds in danger of abandonment) was increasing until 2018, reaching from 174,798.35 euros, in 2015, to the value of 279,364.83 in 2018. And in 2019, the budget allocated for package 8 decreases to the value of 240,294.30. Also, the absorption percentage of the total budget allocated by the EU, of compensatory payments, was continuously increasing, from the value of 44.18% in 2015, to the value of 88.84% in 2019 (Table 5).

## CONCLUSIONS

In the period 2015 - 2019, in Romania, the value of the compensatory payments of package 1 (high natural value meadows) from Measure 10 - Agroenvironment and Climate of PNDR 2014 - 2020, were 231,563,125.73 euros, with a total number of beneficiaries of 212,413 and a total area of 1,799,820 hectares, and the absorption percentage is 97.14% of the total EU budget of 238,282,749.82 euros allocated to this package.

In the period 2015 – 2019, in Romania, the value of the compensatory payments of package 4 (green crops) from Measure 10 – Agroenvironment and Climate of PNDR 2014 – 2020, were 48,975,474.83 euros, with a total number of beneficiaries of 7,506 and a total area of 399,030 hectares, and the absorption percentage is 94.19% of the total EU budget of 51,995,505.11 euros allocated to this package.

In the period 2015 - 2019, in Romania, the value of the compensatory payments of package 8 (breeding of farm animals from local breeds at risk of abandonment) from Measure 10 - Agroenvironment and Climate from PNDR 2014 - 2020, were 801,361.18 euros, which represents an absorption percentage of 70.14% of the total EU budget, from this period, with a value of 1,142,476.22

euros. The total values of the compensatory payments for each species are 17,150.22 euros for goats, 470,194.00 euros for sheep, 96,161.00 euros for cattle, 154,162.36 euros for pigs and 63,693.60 euros for equids.

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# VARIATION OF NITROGEN USE EFFICIENCY FROM MINERAL FERTILIZER ASSOCIATED WITH SOME FOLIAR TREATMENT

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***Abstract***

*The study evaluated the variation in the efficiency of nitrogen use from mineral fertilizers, associated with foliar fertilization in wheat, based on biological yield. Two specific indicators (Agronomic Efficiency - AE, Partial Factor Productivity - PFP) were calculated to quantify the efficiency of nitrogen use. The study was organized within the Didactic and Experimental Resort, BUASVM Timisoara. The 'Alex' wheat cultivar was cultivated, under the conditions of a chernozem type soil, medium fertility, and non-irrigated culture system. The 2020 – 2021 agricultural year was taken into account. Biological yield (BY, g $m^{-2}$) was evaluated at physiological maturity (BBCH code 9, Senescence). Polynomial models of the 2nd degree described the variation of BY in relation to nitrogen (N) on each level of foliar fertilization (Super Fifty – SF), in differentiated conditions of statistical certainty ($p<0.05$ for the SF2 variant). There was an increasing variation in the AE and PFP values associated with foliar fertilization (SF), up to the level of SF2 and SF3 variants (2 – 3 L $ha^{-1}$), followed by a decreasing trend. The regression analysis led to obtaining an equation-type mathematical model that described the BY variation in relation to N and SF, as a direct and interaction effect, under statistical safety conditions ($p<0.001$, $R^2=0.957$). Based on the values of the obtained equation coefficients, the optimal doses were calculated ($x_{opt}=137.05$ kg $ha^{-1}$ N active substance, $y_{opt}=2.92$ L $ha^{-1}$ SF, concentration 1.168 %).*

**Key words:** *agronomic efficiency, biological yield, nitrogen fertilizer, Partial Factor Productivity, wheat*

## INTRODUCTION

Fertilizers represent important inputs in agriculture and at the same time factors with a high contribution in forming plant production and supporting soil fertility [28, 31, 32].
Fertilizers have been studied in relation to soil health and quality [21, 27, 33], the type of agricultural system [9], crop productivity and agricultural production [8, 12, 43], the sustainability of agriculture [21], but also in relation to the production and market of fertilizers [3, 22, 28], and farmers' options for fertilizer resources [20, 38, 41].
Mineral fertilizers are important for sustaining agricultural yields, yields that would decrease with variable percentages in relation to the crop (eg wheat, rice, corn), the type of nutritive element (eg NPK), but also the doses applied and the climate and soil conditions [24, 39, 43].
The rate of fertilizers use varies in relation to different analysis criteria (point of reference, countries and regions, agricultural systems, types of farms, categories of farmers, agricultural crops etc.), depending on socio-economic and ecological conditions [7, 20, 25, 34, 36].
Different methods, techniques, models, each with specific indices and safety parameters, were used to evaluate the use of fertilizers from physico-chemical, biological, ecological, practical, economic perspectives [4, 10, 16, 26, 44].
The efficiency of the use of fertilizers is a topical issue, all the more associated with the economic crisis and the need of farmers to find solutions to support agricultural production in sustainable budgets [2, 45].
Among the nutrients with a major role in the formation of agricultural production, nitrogen has been the most studied in relation to the efficiency of use, in order to optimize the doses of fertilizers [6, 11, 37], productions (quantitative and qualitative) and yields [19, 23], ecosystem protection etc. [1, 11].
The study aimed to evaluate the efficiency of nitrogen utilization from mineral fertilizers applied to the soil, expressed through the lens of biological production in wheat, the 'Alex'

cultivar, associated with foliar fertilization with a biofertilizer product based on algae extracts.

## MATERIALS AND METHODS

The field experiment on the wheat crop, the 'Alex' cultivar, was organized within the BUASVM Timisoara, Didactic and Experimental Resort (DER), Timis County, Romania.

The soil was chernozem type, with medium fertility, and the culture system was not irrigated.

Nitrogen was administered in five doses, between 0-200 kg N a.s. $ha^{-1}$ (a.s. – active substance). Ammonium nitrate was used, in doses that ensured the amount of active substance per variant (0 – N0, 50 kg a.s. $ha^{-1}$ – N50; 100 kg a.s. $ha^{-1}$ – N100; 150 kg a.s. $ha^{-1}$ – N150; 200 kg a.s. $ha^{-1}$ – N200). The fertilizer was applied in the spring, uniformly on each experimental variant.

The Super Fifty product was used in concentrations between 0 – 2% (calculated at a solution amount of 250 L $ha^{-1}$), respectively the following concentrations were used: 0% (SF0), 0.4% (SF1), 0.8% (SF2), 1.2% (SF3), 1.6% (SF4) and 2% (SF5).

From the combination of the two factors, N and SF, 30 experimental variants resulted. The experimental variant had an area of 18 $m^2$, and the experiment was organized in three repetitions, randomized. The 2020 – 2021 agricultural year was considered.

At physiological maturity, BBCH 9 code, Senescence [29], samples were collected to determine biological yield (g $m^{-2}$).

To evaluate the efficiency of nitrogen use from the mineral fertilizer applied on the soil, associated with foliar fertilization, the Agronomic Efficiency – AE [15, 17], relationship (1), and Partial Factor Productivity – PFP [17], relationship (2), were calculated.

$$AE = (BY - BY_0)/F \quad (1)$$

where: AE – Agronomic Efficiency;
BY – biological yield at each dose of N, and each SF level;
$BY_0$ – biological yield in the control variant (N0), on each SF level;
F – the dose of N corresponding to the biological yield (BY).

$$PFP = BY/F \quad (2)$$

where: PFP – Partial Factor Productivity;
BY – biological yield at each dose of N, and each SF level;
F – the dose of N corresponding to the biological yield BY.

The PAST software [18], the Wolfram Alpha software [40], and mathematical module in EXCEL (Office package) were used for the analysis and mathematical and statistical processing of the data, and for the graphs generated.

## RESULTS AND DISCUSSIONS

The study quantified the level of biological yield (BY, g $m^{-2}$) in wheat, the 'Alex' cultivar, under the influence of mineral fertilization with nitrogen (ammonium nitrate) associated with foliar fertilization with the Super Fifty product (SF).

The values recorded for biological yield, in relation to the two factors (N, SF) are presented in Table 1.

The increase in biological yield in relation to nitrogen (N) was found, up to around the dose of 150 kg $ha^{-1}$ N a.s. Also, the increasing variation of biological yield was found in relation to the Super Fifty product, up to the SF3 variant (3 L $ha^{-1}$, 1.2%).

The study investigated the variation of N use efficiency, associated with foliar treatments (SF) based on the recorded biological yield (BY, g $m^{-2}$).

Thus, the variation of biological yield (BY) generated by N, associated with the six levels of foliar treatments with the Super Fifty product (SF), was described by equations (3) – (8), under statistical safety conditions, Table 2; in the equations (3) - (8) *x* represents the doses of N.

Table 1. Values of biological yield in relation to N and SF, the 'Alex' wheat cultivar

| Nitrogen (N) | Super Fifty (SF) | | | | | |
|---|---|---|---|---|---|---|
| | SF0 | SF1 | SF2 | SF3 | SF4 | SF5 |
| | Biological Yield (BY, g m$^{-2}$) | | | | | |
| N0 | 1,139 | 1,207 | 1,238 | 1,372 | 1,443 | 1,409 |
| N50 | 1,278 | 1,473 | 1,443 | 1,728 | 1,508 | 1,509 |
| N100 | 1,339 | 1,479 | 1,490 | 1,733 | 1,530 | 1,527 |
| N150 | 1,494 | 1,599 | 1,673 | 1,890 | 1,670 | 1,665 |
| N200 | 1,379 | 1,548 | 1,667 | 1,763 | 1,658 | 1,604 |

Source: Original data from the experiment.

Table 2. The equations that describe the variation of BY in relation to N and foliar fertilization levels, the 'Alex' wheat cultivar

| Foliar treatment | Equation | Equation number | $R^2$ | p |
|---|---|---|---|---|
| SF0 | $BY_{SF0} = -0.0118x^2 + 3.758x + 1{,}127$ | (3) | 0.886 | 0.114 |
| SF1 | $BY_{SF1} = -0.0148x^2 + 4.587x + 1{,}225$ | (4) | 0.924 | 0.076 |
| SF2 | $BY_{SF2} = -0.00817x^2 + 3.81x + 1{,}244$ | (5) | 0.957 | 0.042 |
| SF3 | $BY_{SF3} = -0.0233x^2 + 6.555x + 1{,}391$ | (6) | 0.913 | 0.087 |
| SF4 | $BY_{SF4} = -0.00103x^2 + 1.39x + 1{,}438$ | (7) | 0.901 | 0.098 |
| SF5 | $BY_{SF5} = -0.00577x^2 + 2.246x + 1{,}405$ | (8) | 0.862 | 0.138 |

Source: Original equations and values, based on experimental data.

In order to more precisely quantify the way in which the efficiency of nitrogen use changes, associated with foliar treatments (SF), were used two specific indicators regarding NUE, proposed by specialized literature, Agronomic Efficiency – AE [15, 17], and Partial Factor Productivity – PFP [17].

Agronomic Efficiency (AE) was calculated based on the relationship (1) for each experimental variant, in order to evaluate the efficiency of nitrogen (N) in the applied doses, associated with each foliar treatment (SF), in terms of biological yield (BY), and the values obtained are presented in Table 3.

Table 3. The values of the AE index on experimental variants, in relation to biological yield, the 'Alex' wheat cultivar

| Trials | SF0 | SF1 | SF2 | SF3 | SF4 | SF5 |
|---|---|---|---|---|---|---|
| N0 | - | - | - | - | - | - |
| N50 | 2.78 | 5.32 | 4.10 | 7.12 | 1.30 | 2.00 |
| N100 | 2.00 | 2.72 | 2.52 | 3.61 | 0.87 | 1.18 |
| N150 | 2.37 | 2.61 | 2.90 | 3.45 | 1.51 | 1.71 |
| N200 | 1.20 | 1.71 | 2.15 | 1.96 | 1.08 | 0.98 |

Source: Original data obtained by calculation.

On each level of N, an increasing variation of AE associated with foliar treatments (SF) was found, up to the SF3 variant, after which a decrease in AE values followed.

Partial Factor Productivity (PFP) was calculated based on the relationship (2), and the recorded values are presented in Table 4.

Also in the case of this index, the increase of PFP values was found for each level of N associated with the foliar treatments up to variant SF3, after which followed a downward trend.

Table 4. The values of the PFP index on experimental variants, in relation to biological production, the 'Alex' wheat cultivar

| Trials | SF0 | SF1 | SF2 | SF3 | SF4 | SF5 |
|---|---|---|---|---|---|---|
| N0 | - | - | - | - | - | - |
| N50 | 25.56 | 29.46 | 28.86 | 34.56 | 30.16 | 30.18 |
| N100 | 13.39 | 14.79 | 14.90 | 17.33 | 15.30 | 15.27 |
| N150 | 9.96 | 10.66 | 11.15 | 12.60 | 11.13 | 11.10 |
| N200 | 6.90 | 7.74 | 8.34 | 8.82 | 8.29 | 8.02 |

Source: Original data obtained by calculation.

In the case of both indices considered (AE, PFP), the degree of N utilization, based on biological yield (BY), recorded decreasing values with increasing doses of N, at each level of foliar fertilization (SF). At the same time, there was an increase in the degree of N use, respectively N efficiency in biological yield (BY), associated with foliar fertilization. The graphic representation in Figures 1 and 2, illustrates the variation of the AE index (Figure 1) and PFP index (Figure 2), in relation to nitrogen fertilizers (N) and the foliar biofertilizer Super Fifty (SF).

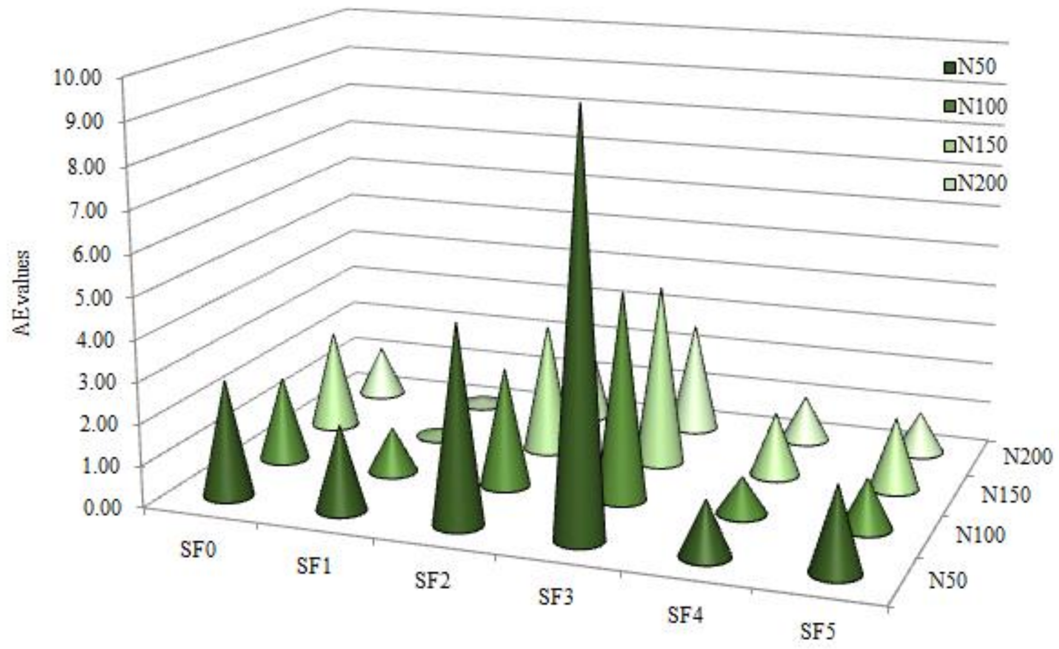


Fig. 1. The graphic distribution of the AE index values in relation to N and SF, the 'Alex' wheat cultivar
Source: original graphic based on calculated data.

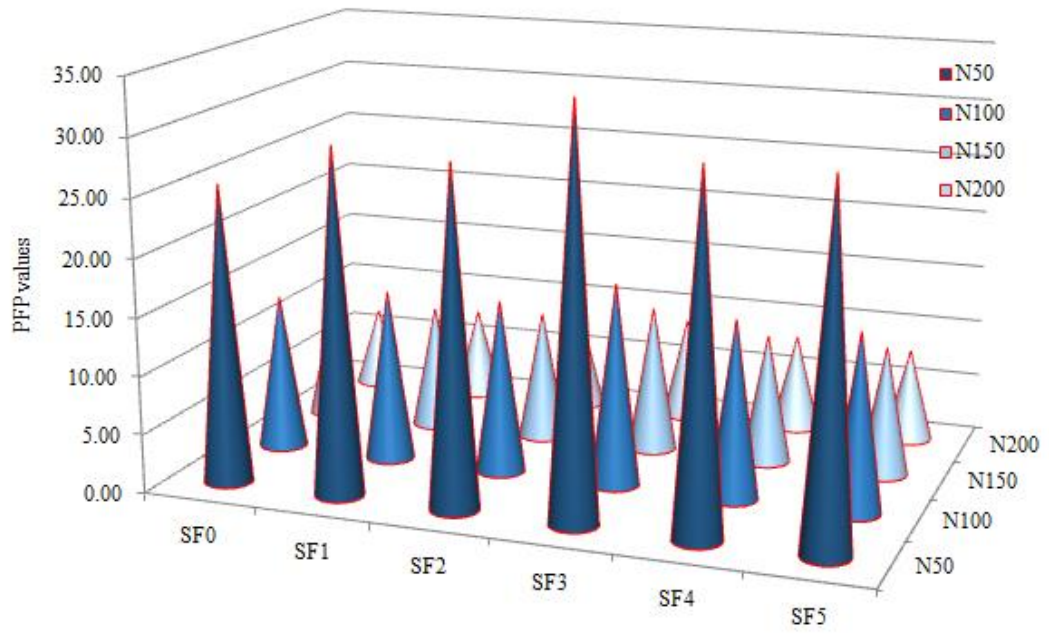


Fig. 2. Graphical distribution of the PFP index values in relation to N and SF, the 'Alex' wheat cultivar
Source: original graphic based on calculated data.

Based on the regression analysis, equation (9) was obtained that described the variation of biological yield (BY) in relation to nitrogen from mineral fertilizer (N), and foliar biofertilizer (SF), as a direct and interaction effect, under statistical safety conditions ($R^2$=0.957, p<0.001, F =113.92).

For high precision of the calculations, the values of the coefficients of equation (9) had up to 16 decimal places. The graphic distribution of biological yield (BY) values in relation to N and SF is presented in 3D form in figure 3, and in the form of isoquants in Figure 4.

The ANOVA test confirmed the safety for the parameters of equation (9); p=0.0191 for a, p=0.0046 for b, p<0.001 for c and d, respectively p=0.0011 for e.

$$BY = ax^2 + by^2 + cx + dy + exy + f \qquad (9)$$

where: BY – biological yield;
$x$ – Nitrogen dozes (N, kg a.s. $ha^{-1}$);
$y$ – Super Fifty (SF, L $ha^{-1}$);
a, b, c, d, e, f – coefficients of the equation (9);
a= -0.03527791;
b= -72.24608555;
c= 14.21481840;
d= 635.36592413;
e= -1.55564616;
f= 0

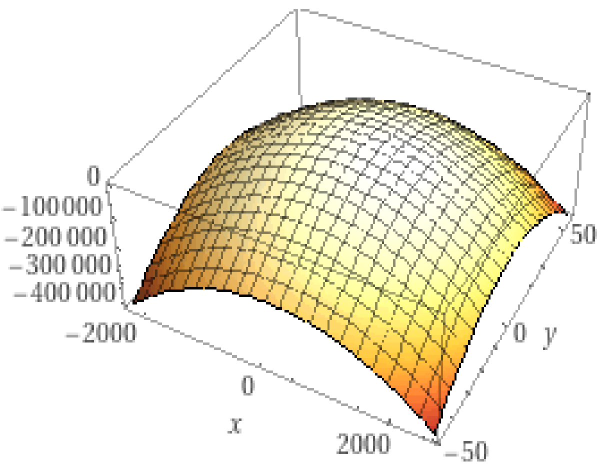


Fig. 3. 3D model of the BY variation in relation to the dose of nitrogen, N (x-axis) and SF (y-axis), the 'Alex' wheat cultivar
Source: Original graph.

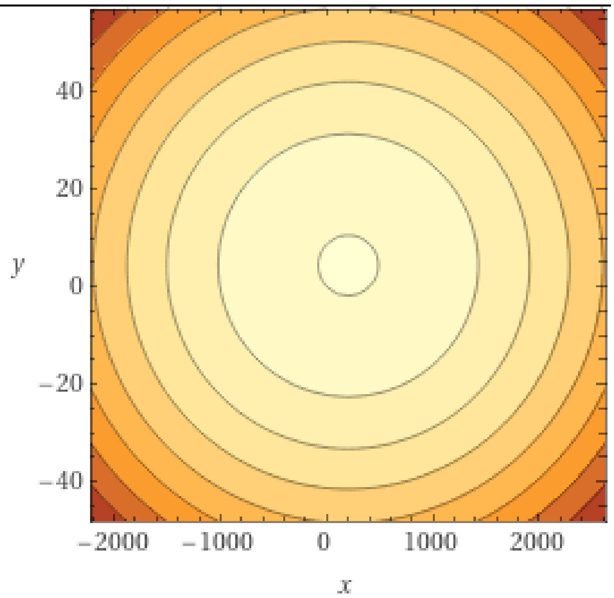


Fig. 4. Graphic representation in the form of isoquants, for the biological yield (BY) variation in relation to the dose of nitrogen, N (x-axis) and SF (y-axis), the 'Alex' wheat cultivar
Source: Original graph.

Based on the values of the coefficients of equation (9), the optimal doses for N and SF in relation to biological yield were calculated, and resulted the values $x_{opt}$=137.05 kg $ha^{-1}$ N (a.s.) and $y_{opt}$=2.92 L $ha^{-1}$ SF (concentration, 1.168 %).

To increase N efficiency, were studied different methods and techniques of fertilizer application [42], complex and alternative fertilization [5, 14], foliar fertilization with elements to potentiate N utilization [13], the use of performing genotypes [35], appropriate culture strategies and technologies [30] etc.

In the case of the present study, foliar fertilization with the Super Fifty product, based on algae extract, was taken into account, and the recorded results highlighted, based on the two indices (AE and PFP), the increasing variation of N use efficiency associated with SF.

The variation of p values, as a statistical safety parameter (Table 2), from p=0.114 in the case of SF0, to p=0.138 in the case of SF5, with the value of p=0.042 (p<0.05) in the SF2 variant, confirms the range of concentrations (SF2 to SF3 variants), where the optimal dose for SF was obtained, respectively $y_{opt}$=2.92 L $ha^{-1}$.

This value for SF led to the optimal utilization of N, in the experimental conditions, where

$x_{opt}$=137.05 kg ha$^{-1}$ N (active substance).

The authors appreciate that the obtained results can contribute to the optimization of the fertilization system and to the improvement of wheat cultivation technology, in order to increase the efficiency of nitrogen use, with technological and environmental benefits.

## CONCLUSIONS

Mineral fertilization with nitrogen led to the variation of biological yield (BY, g m$^{-2}$) in relation to the doses administered, in the range of 1,139 – 1,890 g m$^{-2}$.

Foliar administration of Super Fifty biofertilizer, at each nitrogen level, led to a corresponding variation in biological yield.

The efficiency of nitrogen use, provided by mineral fertilization, estimated based on biological yield, registered a positive variation associated with foliar fertilization with the Super Fifty product, aspect quantified based on the calculated indices (AE and PFP).

The regression analysis facilitated finding a mathematical model for the BY variation in relation to N and SF, and the optimal doses were calculated, $x_{opt}$=137.05 kg ha$^{-1}$ N (a.s.), $y_{opt}$=2.92 L ha$^{-1}$ SF.

The obtained results can be considered for the optimization of fertilization and wheat cultivation technology, with positive economic, ecological and social aspects.

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# FEATURES OF REGIONAL PRODUCTION OF SUNFLOWER SEEDS IN THE PERIOD 1990-2021 IN UKRAINE

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***Abstract***

*This paper aims to provide analysis of the main features of regional production of sunflower seeds in Ukraine. To realize aims in the article, the importance of agriculture was pointed and evaluation of sunflower seeds productions in accordance with natural and climatic zones were done. Results showed that areas under sunflower have increased significant and in 2021 there was observed the share of 52% of the harvest collected by agricultural enterprises in the Steppe zone, 39% in the Forest-steppe zone, and 9% in the Polissya zone. Grouping enterprises under the area size of sunflower growing confirmed the fact that the bigger arable land of sunflower has the enterprise, the more productive will be sunflower production, in particular, enterprises that have arable land under sunflower more than 2000 ha get yield more than 24 centners per hectare. These enterprises have possibilities to use new technologies to achieve the desired effect during production. The area and introduced pesticides factors was taken into account in regression analysis due to the importance of both them in increasing sunflower seeds production. Results showed close dependence between mentioned factors. In the article discussed a few aspects regarding the sunflower seeds market in Ukraine under the condition of the hostilities in the region. There are evaluated experts opinions regarding production capacities, processing, export and prices on the domestic and world market.*

***Key words***: *regional production, sunflower seeds, sunflower oil, war, logistics, regression*

## INTRODUCTION

Sunflower is one of the main oilseed crops in Ukraine. Production is concentrated mainly in the Southern and Eastern regions. Due to favourable combination of high price, relatively low cost of production, and traditionally high demand, sunflower seed has become one of the most profitable crops. Its high profitability growing furthered a significant expansion in planted area beginning in the late 1990's [18]. Many Ukrainian farmers and enterprises rejected the traditional crop-rotation practices that were recommended by agricultural officials. Such tendency takes place due to technological progress in sunflower growing and its high profitability. In terms of economic efficiency indicators, oilseeds exceed other agricultural crops. According to the Oilseed Institute, the new challenges that have appeared to agriculture are connected with the hostilities in the region [9].

Thus, the underachieved harvest of agricultural crops is estimated at 9.6 billion dollars. The most significant declines in the projected 2022 harvest are for wheat production (a 33% decline compared to the baseline scenario), sunflower (32%) and barley (31%), as a large part of the production of these crops is located directly in the regions affected by hostilities.

One of the consequences of the hostilities in the region is the decline in producer prices for export-oriented goods. Due to the blockade of ports, Ukraine faced oversaturation of the domestic market and an almost four-fold increase in the cost of export logistics. This led to a 30% drop in prices within the country, as a result of which agricultural enterprises lost 11.9 billion dollars [4, 19].

Research on sunflower seeds in view of economic, social and environmental dimensions over the last decade has been widely reflected in the Ukrainian and foreign literature.

Economic issues of sunflower seeds production were researched by Chekhov and Chekhova (2018), where was evaluated the efficiency of sunflower seeds production [3]. There was concluded that sunflower seeds growing in Ukraine is economically beneficial for enterprises. Herewith lower cost prices at the highest price compared to other oil products crops explain the popularity of sunflower seeds and its annual production growth.

Market research of this culture was analyzed in view of the growing linkage of Ukrainian and world markets of sunflower oil [7]. There was stated that high price transmission between the Ukrainian and European markets, however opposite to it lower price transmission was observed among the Ukrainian and United States markets.

Hamulczuk et al (2021) in their publication evaluated the closeness of integration of the Ukrainian sunflower oil market with the European market in the frame of the time varying [5].

Pricing mechanism, pricing analysis conjuncture are presented in the studies of Shpychak (2012), Bodnar (2015), Makarchuk and Kuts (2022) [1, 14, 8].

Mykhailov et al (2020) researched production of sunflower seeds in Ukraine and its economic and technical efficiency, in particular, the technical means of post-harvest processing of sunflower seeds; theoretical issues of the separation of airborne impurities; methodological aspects in research of experimental devices; laboratory and field results of experimental devices and practical application and evaluation of their efficiency [10].

A linkage of technological processes with natural biological processes was studied by Rotaru and Nastase (2014) [12]. They considered that the effectiveness of implication of intensive technology should be based on technical, economic, energy and environmental criteria's.

Soare and Chiurciu (2018) evaluated the main tendencies worldwide regarding the production and marketing of sunflower seeds [15]. There were analyzed indicators that related to the production and marketing of sunflower seeds, i.e. planted areas with sunflower; overall rate of production of sunflower seeds; quantity of fertilizer used for the sunflower production; average yield per hectare of sunflower seeds; its consumption; imports and world exports. They suggested that in the future is expected as planted area to grow worldwide and also to increase sunflower seeds production.

Nowadays new challenges for agriculture crops come due to the war in Ukraine. Many domestic and foreign organizations evaluate the influences and future consequences in agriculture crops growing, production and realization in Ukraine. On evaluation of some agricultural experts, many enterprises in these conditions, i.e. Cyngent Agrocompany, wheat crops will not growing because of low grain price and expensive logistics and instead of it will increase the part of oilseeds due to their higher prices and lower influence of logistic factor.

In these circumstances, our research is actual because of its regional evaluation of sunflower seeds production.

The paper is organized as follows: Section 2 discusses described the data and methods of empirical investigation; Section 4 reports getting results; and Section 5 ends with conclusions of obtained results.

## MATERIALS AND METHODS

The purpose of the article is to analyze features of regional production of sunflower seeds in Ukraine; evaluate factors influencing production growth; forecast further production capacity.

The methodical basis of the research is the provision of statistical data on agricultural crops production, in particular, sunflower seeds. Based on statistical observation about sunflower seeds there were analyzed sown area, yield and production. To achieve the goal in the paper was evaluated Ukrainian sunflower production in accordance with natural and climatic zones. At the same time there was used data on agricultural enterprises grouping by harvested area size under sunflower seeds to see changes in gross harvest and yield depending on the arable land of the enterprise.

Many factors are influencing on sunflower seeds production in each regions of Ukraine. To evaluate the dependence of sunflower seeds production in regions in Ukraine two factors were taken into account, i.e. area under sunflower seeds and introducing pesticides. The source of data was the State Statistics Service of Ukraine for the period 2020 across regions of Ukraine. In the paper was done regression analysis between mentioned signs. There is should be executed the condition that withthe increasing of arable land for sunflower seeds production and growth of pesticides implication, could be got additional sunflower seeds production.

Due to the uncertainty regarding the harvest in the conditions of the war in Ukraine and, accordingly, gross production, the article used a descriptive analysis of production forecasting based on expert assessments and official statements of government.

## RESULTS AND DISCUSSIONS

Ukraine has always been known as an agrarian county with its rich natural potential, i.e. more than 55% of Ukrainian territory consists of arable land, where 66% of this is covered "chornozem" that means black earth that is the most fertile soils in the world and profits from favourable climatic conditions for planting [6]. Agricultural crops grown in Ukraine are represented by the following main groups: grain and leguminous crops; industrial crops; potatoes, vegetables and cucurbitaceous crops and fodder crops. From 1990 to 2020, it is possible to observe a change in the size of the sown areas of the crops and their structure (Table 1). Agricultural producers of all forms of ownership increased the sowing of grain and industrial crops, while reducing the areas under potatoes, vegetables and fodder crops.

At the same time, the cultivated areas under industrial crops expanded most significantly, i.e. from 3,751 thousand ha (12% of the total sown area) in 1990 to 9,224 thousand ha (33%) in 2020.

Table 1. Sown area under agricultural crops and its structure in Ukraine, thousand ha

| Crops area | 1990 | 2000 | 2010 | 2020 | 2020 in % to 1990 |
|---|---|---|---|---|---|
| All sown area | 32,406 | 27,173 | 26,952 | 28,147 | 86.9 |
| Grain and leguminous crops | 14,583 | 13,646 | 15,090 | 15,392 | 105.6 |
| Industrial crops | 3,751 | 4,187 | 7,296 | 9,224 | 245.9 |
| Potatoes, vegetables and cucurbitaceous crops | 2,073 | 2,277 | 1,967 | 1,854 | 89.4 |
| Fodder crops | 11,999 | 7,063 | 2,599 | 1,677 | 13.9 |

Source: Statistical Services of Ukraine, 2022 [16].

In turn, the dynamics of changes in the structure of sown areas of industrial crops have it sown characteristics, in particular, expansion of sunflower, soybean and rapeseed and reduction of fields under sugarbeet and other technical crops (flax, hemp, tobacco, hop); sunflower has remained the main crop in the structure of industrial plants sown area in Ukraine and its share increased from 44% in 1990 to 70% in 2020 (Table 2).

Table 2. Sown area under industrial crops and its structure in Ukraine, thousand ha

| Crops area | 1990 | 2000 | 2010 | 2020 | 2020 in % to 1990 |
|---|---|---|---|---|---|
| All sown area | 3,751 | 4,187 | 7,296 | 9,224 | 245.9 |
| Sugar beet | 1,607 | 856 | 501 | 220 | 13.7 |
| Sunflower | 1,636 | 2,943 | 4,572 | 6,457 | 394.7 |
| Soya | 93 | 65 | 1,076 | 1,351 | 1,452.7 |
| Rapeseed | 90 | 214 | 907 | 1,127 | 1,252.2 |
| Othercrops | 325 | 109 | 240 | 69 | 21.2 |

Source: Statistical Services of Ukraine, 2022 [16].

At the producer level, the choice of crops was determined by various factors. As our research shows, such a change in the ratio of industrial crops sowing is primarily due to economic factors, namely the growing demand for sunflower, soybean and rapeseed both in the domestic and foreign markets, and the sufficiently high level of prices for products during the analyzed period.

As a result of active development of agricultural production, now Ukraine is one of the world's top agricultural producers and exporters of oilseeds to the global market. In the rank among global exporters, Ukraine has taken first place for sunflower oil and sunflower meal. In the percentages expression

Ukrainian export of sunflower oil is amounted to 34.7%, sunflower meal – 39.8%. Ukrainian rapeseed goes mostly for export (more than 90%) and in global export it is amounted to 16.6%. Last decade the arable land under soybean production was grown. Herewith Ukraine's soybean production and export account for less than 1% of global output and trade.

The growth of sunflower cultivation requires further analysis of sunflower seed production trends in different regions of Ukraine, taking into account seed sales channels and available capacities for its storage and processing. It is also important to evaluate the consequences of sunflower seed production not only from the point of view of economic results, but also agrotechnical requirements and principles of sustainable development of agriculture.

In Fig. 1 is analyzed the dynamics of sunflower seeds production and the yield level over the past thirty years, 1990-2020.

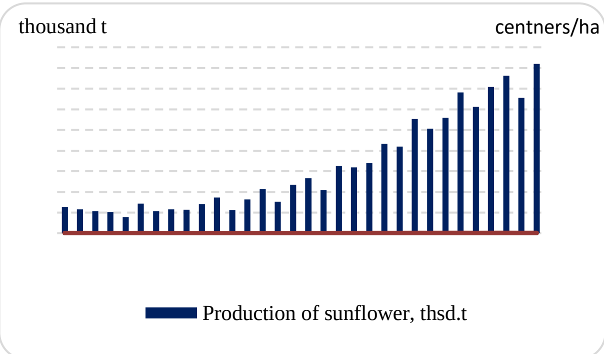


Fig. 1. Dynamics of sunflower seed production and yield in Ukraine in the period of 1990-2020
Source: Presented based on the Statistical Services of Ukraine data, 2022 [16].

From Fig. 1, we can distinguish two conditional periods: the first is the period of post-Soviet development, which lasted until 2000, when a fall in gross revenue or its fluctuations were observed.

The level of production was determined mainly by natural and climatic conditions, since the enterprises had a certain deficit of material and technical support of production and financial resources.

The second period since 2000 has become the stage of active increase in production volumes. The total production of sunflower increased 4.7 times (from 3,457 thousand t in 2000 to 16,392 thousand t in 2021) with an increase in average yield by 42% [16]. Over the last years, the business model has changed, which was aimed at increasing the intensity of technologies and their efficiency, i.e. quality seeds, fertilizers, pesticides, modern technologies, machinery and equipment began to play an increasingly important role.

Ukraine is characterized by regional specialization in the cultivation of oil crops. The farms in the Steppe zone traditionally specialized in growing sunflower as shown in Fig. 2.

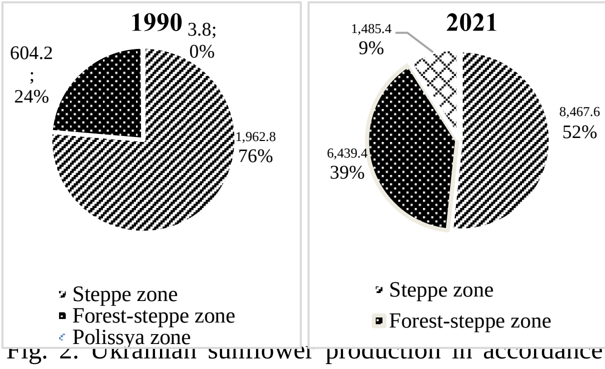


Fig. 2. Ukrainian sunflower production in accordance with natural and climatic zones
Source: Presented based on the Statistical Services of Ukraine data, 2022 [16].

As it is shown in Fig. 2, their share in the total harvest in 1990 was 76%, in particular the agricultural enterprises of Dnipropetrovsk region (12%), Donetsk (11.8%), Zaporizhya (11.1%), Kirovograd (9.8%), Odesa (9.2%), Mykolaiv (8.6%) and Luhansk (8.5%). Among farms in the Forest-steppe zone, the most sunflowers were grown in Kharkiv (9.6%) and Poltava (6.8%) regions.

During the analyzed period we can observe that sunflower production areas have expanded significantly. In 2021, 52% of the harvest was collected by agricultural enterprises of the Steppe zone, 39% of the Forest-steppe zone, and 9% of the Polissya zone. The share of the Kirovograd region in the formation of the gross sunflower harvest in 2021 was amounted to 9.7%, respectively, Dnipropetrovsk 8.6%; Mykolaiv 7.1%; Zaporizhya 6.5%; Odesa 5.9%; Luhansk 4.9%; Donetsk 4.8% and Kherson 4.1%.

Among the regions of the Forest-steppe zone, the most sunflowers were harvested in the following regions: Kharkiv (8.7%); Poltava (6.1%), Vinnytsya (6%); Cherkasy (4.9%); Sumy (4.8%).

The promotion of sunflower cultivation in the central and northern regions of Ukraine is to some extent explained by climate change, namely, the farms of the east and south, due to the arid weather conditions of the last decade, observe a negative impact not only on the yield, but also on the oil content of seeds [13].

Considering the importance of production growth, there was analyzed groupings of enterprises by harvested area size of sunflower seeds (Table 3).

The results of grouping give information that the share of enterprises that are growing sunflower on the area, which no more than 100 ha is amounted to 58.1% and those enterprises that have more than 1,000 ha equal to 5.2%. However, in contrast to this fact the yield in enterprises with land lower than 100 have yield 21.4 centner/ha, where enterprises with land more than 1,000 ha have a greater yield accounting for 24.6 centner/ha. It could be explained that enterprises with lager land have potential to increase yield using modern technologies by growing sunflower.

Table 3. Groupings of enterprises by harvested area size under sunflower seeds in Ukraine in 2020

| Groups | Number of enterprises | | Gross harvest | | Yield, centners per ha |
|---|---|---|---|---|---|
| | Units | percentage to total number | thousand t | percentage to total gross harvest | |
| Enterprises of which with area, ha | 21,856 | 100.0 | 11,492.9 | 100.0 | 21.4 |
| no more than 100.00 | 12,692 | 58.1 | 771.2 | 6.7 | 16.4 |
| 100.01–200.00 | 2,894 | 13.2 | 829.3 | 7.2 | 19.6 |
| 200.01–500.00 | 3,424 | 15.7 | 2,267.4 | 19.8 | 20.7 |
| 500.01–1,000.00 | 1,704 | 7.8 | 2,496.8 | 21.7 | 20.8 |
| 1,000.01–2,000.00 | 824 | 3.8 | 2,458.9 | 21.4 | 22.1 |
| 2,000.01–3,000.00 | 181 | 0.8 | 1,070.9 | 9.3 | 24.7 |
| more than 3,000.00 | 137 | 0.6 | 1,598.4 | 13.9 | 24.6 |

Source: Statistical Services of Ukraine, 2022 [16].

The modern production of competitive sunflower seeds products is possible only on the basis of a growing culture of farming; increasing soil fertility is a necessary condition for the introduction of advanced agricultural technologies with the rational use of local soil and climate resources, means of intensification and the crop rotation system. According to the Methodological recommendations on the optimal ratio of agricultural crops in crop rotations of different soil and climatic zones of Ukraine, the area of sunflower seeds in the Steppe zone should be optimized [20]. Besides that, sunflower should be grown no more than once every seven years on the same field. The positive effects of this method are the prevention of soil-borne fungal diseases and the reduction of moisture and soil fertility depletion. However, nowadays sunflower production can be observed in all regions of Ukraine, despite non-traditional cultivation by region and non-observance of crop rotation.

Due to the significant variability of weather conditions in recent years, the main place in sunflower production should be occupied by highly adaptive hybrids, resistant to drought and stressful temperature increases, as well as resistant to significant fluctuations in temperature and moisture supply during the growing season. The modern level of selection ensures the creation of hybrids with a potential yield of 4.5–5 t/ha. However, realizing the potential of hybrids is impossible without ensuring disease resistance through the use of pesticides and appropriate fertilizes.

To see how sunflower seeds (SSeeds) production depends on two factors harvested area (h_area) and pesticides use (p_use) regression analysis was made (Table 4). The importance of these two factors was mentioned above.

Getting results confirmed the dependence of sunflower seeds production from factors that were included in the model, i.e. with increasing of 1 thousand hectare arable land of sunflower in the region, sunflower seeds production will increase by 1.26 thousand t; implication of pesticides in the quantity of 1 t in the region will lead to sunflower seeds production growth by 0.28 thousand t.

The regression analysis describes close connection between these two factors, where the index R=0.97 indicates a tight linkage.

The model is significant that is confirmed by P-value for the parameter $a_1$ and $a_2$, which are lower than critical value 0.05.

Table 4. Regression analysis results of main factors influence on sunflower seeds production in Ukraine

| Specification | Regression equation: SSeeds_production= -87.69+1.26 *h_area+0.28 p_use |
|---|---|
| R | 0.97 |
| $R^2$ | 0.95 |
| P-value for parameter $a_1$ | 0.00 |
| P-value for parameter $a_2$ | 0.00 |

Source: author's calculations.

A produced sunflower seed goes mostly to domestic oil and fat plants. According to the regions of sunflower cultivation, the main oil and fat plants are located in the Dnipropetrovsk, Zaporizhi, Odesa and Mykolaiv regions.

A feature of the domestic oil and fat industry is a high level of production concentration. More than half of the production capacity of the industry belongs to large industrial groups, the specific weigh to which in the total volume of production is constantly increasing. The industry is characterized by the use of resource-saving technologies, a high level of competition, the investment attractiveness of enterprises, their export orientation and participation in the country's food security.

The largest share in the total production of unrefined oil in 2019 was occupied by Dnipropetrovsk OEZ (16.1%), Delta Wilmar Ukraine (13.6%), POEZ-Kernel Group (11.8%), PP "Oliyar" (7.7%), Prikolotnyanskiy OEZ (6.7%) [2].

Indeed, created oilseed processing facilities in Ukraine make it possible to process the entire harvest (soybean, rapeseed, sunflower). Over the past five years, the average annual production capacity for oilseed processing has increased by 8,256.4 thousand t and as of April 1, 2020 was amounted to 18,813.2 thousand to sunflower processing and 2,762.8 thousand t of soybeans processing [2].

The hostilities in the region started in February 2022 will affect the forecast of sunflower seeds production and its processing. According to official data of the Ministry of Agrarian Policy and Food of Ukraine, the projected sowing area of the main spring agricultural crops for the 2022 harvest in the territory controlled by Ukraine amounted to 14,163.4 thousand hectares, which is 2,752.9 thousand hectares less than in the last year. During the 2022 sowing campaign, a high change in the structure of crops concerned wheat, corn, sunflower and soybeans has been noticed. The planted area with sunflower decreased compared to last years and was equalled to 4.7 million hectares, representing 72% of last year's level. The reduction in cultivated areas will lead to a decrease in production volumes to 9-10 million t, meaning by 40% less than in the previous years [9].

As a result, we can highlight the following possible situations on the market in Ukraine that require further research and development:

(1) the domestic level of sunflower oils consumption will be stable and national food safety will be guarantee in the near term;

(2) at the level of the agricultural producer and processing enterprises, the priority of the channel of sunflower seeds sale to processing enterprises will be preserved; herewith in country could appear a disbalance between the processing capacities that are working and able to work and the amount of sunflower grown. Nowadays several oil extraction plants are partially or completely out of business. Some of them are in the war zone or in the occupied territories.

(3) at the level of the processing enterprises, the market for finished oil products will be a major problem, as logistics and supply chains are significantly disrupted in the conditions of blocked ports. The actual export of sunflower oil amounted to 628,807 t and export of meal was 262,306 t during March-June 2022. It is significantly less than the indicators of the same period of last years [9];

(4) on the vegetable oil market it could be observed certain price fluctuations; however the priority problems for this market participants will be the ability to manufacture products and, most importantly, the ability to sell them.

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## CONCLUSIONS

Agriculture in Ukraine plays a crucial role in national economy. Indeed, agriculture is the third most important sector of the Ukrainian economy, with a gross domestic product share of 10.5% in 2020 [7].

It is important to note that Ukraine is one of the world's top agricultural producers and exporters and plays a critical role in supplying oilseeds and grains to the global market.

Scrutinized the production of sunflower seeds in the last thirty years, the interval could be divided into two periods:

(1) the period of post-Soviet development that continued until 2000, which stood out in gross revenue fall and its fluctuations due to significant shortage of material and technical assist of production and financial resources;

(2) the period since 2000 which is distinguished by increase in production volumes, aimed by using the intensity growing technologies, in particular, quality seeds, fertilizers, pesticides, machinery and equipment etc.

Due to favorable natural and climatic conditions for sunflower growing, its production was widespread all over the country. However, the productivity is different from a region to another due to natural and climatic conditions, and that's why in this research work the regions were divided into three groups (i.e. the Steppe, the Forest-steppe and the Polissya) and scrutinized each of them.

The results showed that in 2021, 52% of the sunflower harvest was collected by agricultural enterprises in the Steppe zone, 39% in the Forest-steppe zone, and 9% in the Polissya zone. Sunflower growing in nontraditional zones, i.e. the central and northern regions, could be explained by changes of climate change, where for sunflower growing the conditions are more appropriate in last year's compare to traditional zones (the east and the south), where it could be observed a negative consequence of climate change on yield and the oil content in seeds.

Grouping agricultural enterprises by area size, sunflower production was higher in the enterprises with larger land cultivated with sunflower, productivity is better and vice versa in the enterprises with a smaller area cultivated with this crop, sunflower yield is lower.

Indeed, enterprises cultivating more than 2,000 ha got a yield by 24 centners per hectare higher, while the enterprises having less than 1,000 ha arable land cultivated registered a sunflower yield ranging between 16.4 and 20.8 centners per hectare. These could be explained by the fact that big enterprises have possibilities to invest in new technologies to achieve better productivity results.

Besides of availability of land that influences productivity, pesticides are another the significant factor for increasing production. Both factors were taken into account in regression analysis. The obtained results confirmed a close dependence between sunflower seeds production and the two factors, i.e. arable land cultivated with sunflower and the use of pesticides. These two factors are responsible of 95% of sunflower seeds production.

The war in Ukraine has negative consequences on agriculture sector, in particular in crop growing due to occupied territory, closeness or partially work of fat and oil factories, ports blockade, not possibility to predict harvest etc.

However, according to USDA forecast in 2022/2023 MY, Ukraine will become the world's third-largest sunflower seeds producer after Russia and the European Union. This is due to the fact that production is expected to go down sharply reflecting challenges that appears due to the hostilities in the region. Ukraine remains the third producer of sunflower seeds, oil and meal among the global producers in 2022/2023 MY [17].

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# CONSUMER PERCEPTION REGARDING THE SENSORY CHARACTERISTICS OF TRADITIONAL AND REGIONAL PRODUCTS. CASE STUDY

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***Abstract***

*In the present study, we propose to analyze the consumer's perception regarding the sensory characteristics of traditional products. The research was carried out in May 2022 as part of the Traditional Products Raffle that takes place weekly in Bd. Marasti no. 61 Bucharest, and assumed the comparison of the sensory characteristics of four types of cheeses, namely: cheese in fir bark, smoked cheese, cheese with cumin and curd with dill. The tasting was done by 83 people, and the appreciation of sensory properties was measured with the help of non-parametric tests that allowed us to determine consumer preferences regarding traditional dairy products. By using the hedonic test and the scalar method, the data were processed statistically, and based on the obtained results, conclusions were formulated that highlighted the fact that the most appreciated traditional product from the category of those tested was "Smoked cheese" (with 7.06 points), followed by "Cheese with cumin" (6.98 points), "Cheese in fir bark" (6.94 points) and "Curd with dill" (6.71 points). The purpose of the research was to highlight the role that the appreciation of the sensory characteristics of food products has in the valorization of traditional or regional products, but also the application of innovation in obtaining new products that contribute to the development of the local economy and to the increase of income in rural areas.*

**Key words:** *consumer perception, sensory characteristics, traditional products, regional products, cheeses*

## INTRODUCTION

Sensory analysis is a scientific method that evaluates the experimental results that are collected from the sample of consumers or trained or untrained evaluators who express their preferences regarding the characteristics of food products and which are the result of their own, subjective decision, but based on personal experience, by the environmental variables, by the characteristics of the products and that interact with the method of carrying out the survey [5, 6].

Although sensory analysis has often been associated with expressing the opinions of product experts, it currently has a proactive role, creating products based on unique sensory properties identified by consumers in relation to their preferences [11, 13].

Traditionally, sensory analysis was more product-oriented and followed the internal validity of the respective products. That is why it must be completed by marketing that assumes external validity by measuring the behavior of the consumer, therefore of the market [1]. The differences between the two forms of testing are also related to the respondents, the type of stimuli used, the applied scaling methods or the testing method [7, 12].

Realizing an integration of the two ways of verifying consumer preferences can contribute to obtaining useful information in the development of products and the food industry [8, 12].

As far as traditional or regional products are concerned, they are more and more sought after on a market with increasingly processed foods, having the particularity that they do not contain additives, preservatives or other synthetic additions and that they are obtained by methods that contribute to preserving the characteristics their organoleptic properties [15].

At the level of the European Union, there is a voluntary system for labeling these products and indicating their origin through the labeling "protected geographical indication" (PGI), "traditional specialties guaranteed" (SGT), "protected designation of origin" (PDO), which makes these products contribute to the development of the local economy, to the protection of the environment and to the increase of the income of producers in the rural environment [9]. At the same time, these products are considered to be healthier, which makes consumers pay more, starting from the fact that they have much better organoleptic properties, but also have positive effects on health [3, 13].

## MATERIALS AND METHODS

The realization of the research involved, on the one hand, the analysis of specialized literature regarding the role and place of traditional products on the food market, but also in the development of important sectors of the economy, such as tourism, the local economy, etc. On the other hand, it was followed the testing of consumer preferences regarding the sensory characteristics of traditional products in the cheese category, these being some of the most sought-after traditional products, along with fruits and vegetables [2].

In the study, the intrinsic attributes such as appearance, smell, taste, aroma were appreciated with the help of the hedonic test and the scoring scale method, by 83 untrained tasters. The research was carried out in May 2022, and the tasters were represented by customers of the Traditional Products Raffle held weekly at the location in Bd. Marasti no. 61 from Bucharest.

The scoring scale method assesses the respondents' attitude regarding the sensory dimension of food products, depending on which the purchase decision is taken or not [10]. The scoring ranged from 0 to 4, 0 meaning - inadequate, 1 - adequate, 2 - good, 3 - very good and 4 - excellent [4]. The maximum score that can be obtained is 20 points. In relation to the weighting factor specific to each appreciated characteristic and the average score, the weighted average score that places the product in the quality class was determined. Starting from the maximum score, according to the algorithm established by Onete et al., it results that a score that represents between 91-100% of the total score places the analyzed product in the "excellent" quality class, a score that represents between 71-90% of the total score places the analyzed product in the "very good" quality class, a score that represents between 51-70% of the total score places the analyzed product in the "good" quality class, a score that represents between 31-50% of the total score places the analyzed product in the "satisfactory" quality class, and a score representing less than 30% of the total score places the analyzed product in the "unsatisfactory" class.

The hedonic test is a preferential test that was used in order to determine the degree to which consumers positively or negatively appreciated the taste qualities of traditional products, and it involved the awarding of marks between 1 and 9 for each of the samples. The notes were recorded in the evaluation sheets in which the consumers' preferences were classified in relation to the following degrees of appreciation: extremely pleasant, very pleasant, pleasant, weakly pleasant, indifferent (these reflecting the positive sensations) and slightly unpleasant, semi-pleasant, completely unpleasant, extremely unpleasant (they reflect negative feelings). Depending on the determined scores, the best product can be established, but the degree of preference can also be measured. The formula was used to determine the global score:

*Overall score = (N x 9 + N x 8+ N x 7 + N x 6 + N x 5 + N x 4 + N x 4 + N x 3 + N x 2 + N x 1)/ND,*

*where:*
*N - number of tasters who gave the same grade*
*ND – total number of tasters* [14]

Following the centralization of the answers, it was possible to determine the degree of satisfaction or dissatisfaction of the consumers regarding the traditional products from the case study (cheese in fir bark,

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smoked cheese, cumin cheese and dill curd). the obtained results were interpreted statistically and formed the basis of the conclusions. The disadvantage of the hedonic test is represented by the fact that the respondents are influenced by the psychological effect that the analyzed products have on them, as a result of the fact that they compare the sensory properties with those of other similarly known products.

## RESULTS AND DISCUSSIONS

The research was carried out starting from the answers provided by the 83 untrained tasters, of whom 63% were women and 37% were men.

The structure in relation to the level of salary and education is presented in Table 1.

Table 1. Demographic information

| Characteristic | Type | Frequency | % |
|---|---|---|---|
| Sex | Female | 52 | 62.65 |
| | Male | 31 | 37.35 |
| Age | 18-24 years | 14 | 16.86 |
| | 34-54 years | 38 | 45.78 |
| | 54-65 years | 27 | 32.53 |
| | over 65 years | 4 | 4.83 |
| Income level (RON) | 2,000 – 3,000 | 9 | 10.84 |
| | 3,001 – 5,000 | 17 | 20.48 |
| | 5,001 – 7,000 | 18 | 21.69 |
| | 7,001 – 9,000 | 23 | 27.71 |
| | over 9,001 | 16 | 19.28 |
| Education | Secondary education | 27 | 32.53 |
| | Higher education | 52 | 67.47 |

Source: own processing.

Table 2. The frequency of giving scores to traditional cheese samples

| Characteristic | Points | Cheese in fir bark | Smoked cheese | Cheese with cumin | Curd with dill |
|---|---|---|---|---|---|
| Appearance | 4 | 12 | 14 | 19 | 13 |
| | 3 | 42 | 37 | 36 | 29 |
| | 2 | 27 | 26 | 25 | 32 |
| | 1 | 2 | 6 | 3 | 4 |
| | 0 | 0 | 0 | 0 | 5 |
| Smell | 4 | 22 | 19 | 17 | 13 |
| | 3 | 38 | 27 | 35 | 15 |
| | 2 | 26 | 34 | 23 | 27 |
| | 1 | 3 | 18 | 6 | 31 |
| | 0 | 0 | 3 | 2 | 7 |
| Taste | 4 | 19 | 1 | 16 | 13 |
| | 3 | 38 | 25 | 32 | 26 |
| | 2 | 18 | 38 | 23 | 24 |
| | 1 | 5 | 10 | 9 | 11 |
| | 0 | 3 | 6 | 3 | 9 |
| Consistency | 4 | 17 | 19 | 21 | 8 |
| | 3 | 29 | 34 | 31 | 16 |
| | 2 | 27 | 21 | 24 | 32 |
| | 1 | 6 | 7 | 5 | 14 |
| | 0 | 4 | 2 | 2 | 13 |
| Color | 4 | 14 | 19 | 20 | 13 |
| | 3 | 37 | 36 | 28 | 29 |
| | 2 | 21 | 21 | 26 | 33 |
| | 1 | 9 | 4 | 7 | 3 |
| | 0 | 4 | 3 | 2 | 5 |

Source: Own calculation.

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The measurement of consumer perception regarding the sensory characteristics of traditional cheeses was achieved by applying the scoring scale method. The 4 samples (cheese in fir bark, smoked cheese, cheese with cumin and curd with dill) were presented simultaneously, and the ordering criteria were: appearance, smell, taste, consistency and color.

The scoring scale was made up of points given to each appreciated characteristic, these being between 0-4 points.

The manner in which the points were awarded to the 4 products for the appreciation of the 5 characteristics, by the 83 respondents, are presented in Table 2.

By calculating the average score for each individual product and by correcting it with the help of the weighting factor, could determine weighted average scores for the 4 products tested. According to the specialized literature, the weighting factors used in the case of bras were: 0.4 for appearance, consistency and color; 0.8 for smell; 1.2 for taste.

In establishing the quality classes for the 4 samples analyzed, we used the centralizing sheets in order to determine the weighted average scores (Table 3).

Based on the points awarded for the appreciation of the 5 sensory characteristics of the traditional product "Cheese in fir bark", the total average score was 13.78 points out of a total of 20 possible points, which places it in the category of "good" products (69.34 %). The most appreciated sensory characteristic was the smell, for which the average score was 3.10 points. In order of scoring, the tasters appreciated the smell, taste, appearance, color and consistency (Table 3).

Table 3. Weighted average score for "Cheese in fir bark"

| Sensory characteristic | Factor of weighting | Average score | Weighted average score |
|---|---|---|---|
| Apparance | 0.4 | 2.77 | 1.10 |
| Smell | 0.8 | 3.10 | 2.48 |
| Taste | 1.2 | 2.78 | 3.34 |
| Consistency | 0.4 | 2.59 | 1.04 |
| Color | 0.4 | 2.63 | 1.05 |
| Total | | 13.78 | 9.01 |

Source: Own calculation.

For the product "Smoked cheese" a total score of 14.11 points was obtained (71% of the total score), which places it in the category of "very good" products. In order of appreciation of the sensory characteristics, they were: smell, taste, color, appearance and consistency (Table 4).

Table 4. Weighted average score for "Smoked cheese"

| Sensory characteristic | Factor of weighting | Average score | Weighted average score |
|---|---|---|---|
| Apparance | 0.4 | 2.71 | 1.08 |
| Smell | 0.8 | 3.00 | 2.40 |
| Taste | 1.2 | 2.89 | 3.47 |
| Consistency | 0.4 | 2.73 | 1.09 |
| Color | 0.4 | 2.77 | 1.11 |
| Total | | 14.11 | 9.16 |

Source: Own calculation.

The total average score of 13.69 points and the weight of 68% of the total score places "Cheese with cumin" (Cascaval cu chimion", in Romanian) in the category of "good" products. The sensory characteristics were appreciated in the following order: appearance, consistency, smell, taste and color (Table 5).

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Table 5. Weighted average score for "Cheese with cumin"

| Sensory characteristic | Factor of weighting | Average score | Weighted average score |
|---|---|---|---|
| Apparance | 0.4 | 2.86 | 1.14 |
| Smell | 0.8 | 2.71 | 2.17 |
| Taste | 1.2 | 2.69 | 3.22 |
| Consistency | 0.4 | 2.77 | 1.11 |
| Color | 0.4 | 2.59 | 1.03 |
| Total | | 13.69 | 8.67 |

Source: Own calculation

Table 6. Weighted average score for "Curd with dill"

| Sensory characteristic | Factor of weighting | Average score | Weighted average score |
|---|---|---|---|
| Apparance | 0.4 | 2.49 | 1.00 |
| Smell | 0.8 | 2.51 | 2.00 |
| Taste | 1.2 | 2.28 | 2.73 |
| Consistency | 0.4 | 2.53 | 1.01 |
| Color | 0.4 | 2.53 | 1.01 |
| Total | | 12.34 | 7.76 |

Source: Own calculation.

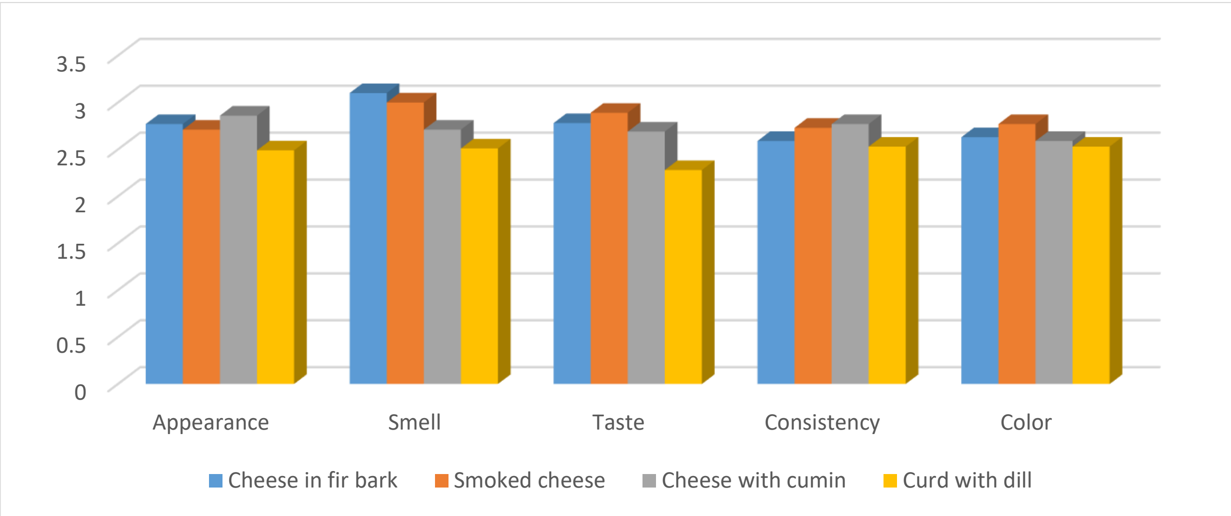


Fig. 1. Distribution of sensory characteristics by product in relation to tasters' appreciation
Source: Own calculation.

The product "Curd with dill" ("Urda cu marar", in Romanian) obtained a total average score of 12.34 points, which represents 62% of the maximum score, thus placing the product in the "good" category from the point of view of the quality class. The respondents first appreciated the taste, then the smell, followed by the consistency and color (with 1.01 points), and finally the appearance, located only 0.01 points after the color and consistency (Table 6).

Figure 1 highlights the most appreciated sensory characteristic of each product, as well as the order of appreciation. Thus, we find that in terms of "appearance", the most appreciated product in relation to this characteristic was "Cheese with cumin" followed by "Cheese in a fir tree basket".

Regarding the "smell", the product that was most appreciated in relation to this characteristic was "Cheese in a fir basket", followed by "Smoked cheese". From the point of view of "taste", the most appreciated product was "Smoked cheese", followed by "Cheese in a fir basket", "Cheese with cumin" and "Curd with dill". In terms of "consistency", the first place was "Cheese with cumin", and the last place was "urfa with

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dill", and in terms of "color", the first place was "Smoked cheese", followed by "Cheese in a fir tree basket", "Cheese with cumin" and "Urda with dill" (Figure 1). Making a ranking of the 4 sensory appreciated products, it turns out that the most appreciated product was "Smoked cheese" with a score of 14.11 points, followed by "Cheese in fir bark" with a score of 13.78 points, "Cheese with cumin" with 13.69 points and then "Urda with dill" with 12.34 points (Figure 2).

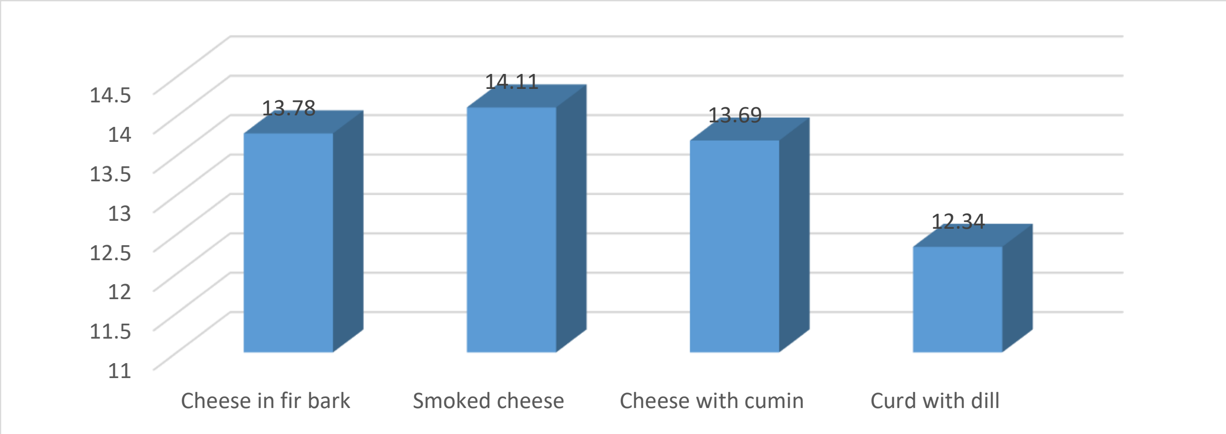


Fig. 2. The ranking of traditional products appreciates in relation to the sensory characteristics
Source: Own calculation.

Table 7. Degree of appreciation

| Degree | Cheese in fir bark | Smoked cheese | Cheese with cumin | Curd with dill |
|---|---|---|---|---|
| Extremely nice (9) | 9 | 11 | 8 | 7 |
| Very nice (8) | 23 | 27 | 31 | 22 |
| Nice (7) | 27 | 23 | 18 | 24 |
| Least liked (6) | 11 | 9 | 11 | 10 |
| Indifferent (5) | 9 | 7 | 7 | 13 |
| Slightly Unpleasant (4) | 2 | 3 | 5 | 4 |
| Half nice (3) | 2 | 3 | 3 | 3 |
| Completely Unpleasant (2) | 0 | 0 | 0 | 0 |
| Extremely Unpleasant (1) | 0 | 0 | 0 | 0 |
| Average | 6.98 | 7.06 | 6.94 | 6.71 |

Source: Own calculation.

In order to verify the tasters' preferences regarding the 4 traditional products, we applied the hedonic test, finding that the highest average score was obtained by the product "Smoked cheese" (with 7.06 points), followed by "Cheese with cumin " (6.98 points), “Cheese in fir bark” (6.94 points) and “Curd with dill” (6.71 points). We find that the order of consumer preference has remained the same, what has changed, but insignificantly, being the degree of appreciation (Table 7).

It follows that the scores obtained place the traditional products tested in the category of accepted products and which induced the tasters positive feelings towards them.

It was found that there is a direct correlation between the salary level and the preference for traditional products, finding that people aged between 34-54 years and 54-65 years are the most interested in traditional products. The level of income is also important, finding that people with incomes over 5,000 Ron are the ones who purchase these products.

Therefore, we find that the use of the 2 methods did not result in significant differences in terms of the degree of acceptance of the traditional products tested, which confirms the fact that the tested people managed to make a sensory assessment in relation to the sensory characteristics perceived by them. Therefore, sensory analysis is one of the methods that must be taken into account when making decisions about the marketing of food products, especially since it is found that it has begun to occupy an increasingly important role in the food industry, being used not only in making marketing decisions regarding the range of products obtained, their positioning on the market, market segmentation and price setting, but also in choosing the target market, depending on the product's characteristics. Therefore, we consider that the quantitative measurement of some sensory characteristics such as: appearance, flavors, aroma, taste, color, texture, etc. is essential for the producer.

## CONCLUSIONS

The tests used in the sensory evaluation of food products are the basis for identifying consumer preferences, being important for the development of products demanded by the market, but also for increasing their quality. At the macroeconomic level we can even talk about the competition of local and global markets. An important aspect that must be taken into account when resorting to sensory analysis is the choice of correct, representative methods so as to avoid the use of irrelevant or wrong results and which, in turn, have a negative impact on the products sold. This can be avoided as long as scientific principles are used that determine objective answers regarding the sensory properties of the researched products. Therefore, what the science of sensory analysis must ensure is the understanding of the importance that sensory characteristics have in consumer acceptance of products.

The reason why we consider and recommend the use of different sensory analysis methods, both discrimination and descriptive, is in the first case to provide information on how the tested products are perceived, and in the second case to identify the characteristics of the products, to measure them, to determine the presence of a characteristic or its intensity.

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# RESOURCE PROVISION FOR THE COMPETITIVE DEVELOPMENT OF FARMING ENTERPRISES IN LVIV REGION: ASSESSMENT OF THE CONDITION AND WAYS OF IMPROVEMENT

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***Abstract***

*The article is devoted to the necessity of competitive development of farming enterprises in Lviv region to ensure food security both at the state and regional levels in particular. As part of the research, a thorough economic and statistical analysis of their economic activity and resource provision was conducted. It has been found that the farming enterprises of Lviv region are characterized by positive trends of development. In particular, there is a consolidation of farmers by the area of land use, an increase in the number of agricultural products, which had a positive effect on the sale of the main types of agricultural products in the region and beyond. The objective necessity is substantiated for intensive development of cooperation of farming enterprises in Lviv region under conditions of unstable financial and economic situation in the state, which will provide an opportunity to attract investment and innovation resources for their effective development, will ensure production of ecologically clean food products and creation of new jobs. Among the priority directions for the development of farming enterprises in Lviv Region, special attention is focused on the diversification of activities, which is expedient to consider in production, technological and marketing aspects. The study proved that farming enterprises of Lviv region have all the prerequisites for effective business management. Their strategic development should be focused not only on increasing the volume of production, but also on improving the quality of products, which will ensure a high level of their competitiveness on domestic and foreign markets.*

***Key words*****:** *competitiveness, resource potential, farming enterprises, agricultural production, effective business management, investments*

## INTRODUCTION

In the conditions of wartime and, therefore, the difficult economic situation in Ukraine, the dynamic development of agrarian entrepreneurship is extremely urgent to ensure the country's food security and to solve many problems of the socio-economic nature of its regions. The growing role of farming as a special form of business, which has the potential to expand the business environment, to form and stabilize the middle class in society, is undeniable today. Considering the current situation, each of farming enterprises aims to increase the profitability of its activities based on the production, processing and sale of agricultural products, provided that all types of resources are used effectively. The question of effective use of resource potential is an integral component of the competitive functioning of all subjects of agrarian entrepreneurship. This problem is especially relevant for farming enterprises, because today they are entrusted with the task of solving the food security of the state, supporting fair competition in the market of agricultural products and solving the social problems of the village. World experience confirms that farming has a high degree of adaptability to market signals, which allows them to have certain advantages compared to medium and large agricultural enterprises. However, the lack of working capital, a weak material and technical base, the complexity and constant change of the taxation system, the instability of state support restrain the development of farming enterprises in the domestic economy. Therefore, in the future, the production and economic activity of farmers requires a constant search for mechanisms that would ensure their effective functioning and competitive development.

In the economic literature, the business activity of farming enterprises is studied in various aspects. A significant contribution to the development of theoretical and practical issues in this field was made by domestic scientists, namely: Berezivskyy P.S. [3], Borodina O.M. [4], Cherevko G.V. [5], Hubeni Yu.E. [6], Ihnatenko M.M. [7], Kropyvko M.F. [8], Lupenko Yu.O. [9], Lypchuk, V.V. [10], Shpykuliak O.H. [11], Shulskyi M.H. [12], Skrypnyk S.V. [13], Yatsiv I.B. [14], Yavorska T.I. [15], and others. In particular, Professor G. Cherevko is convinced that in the future farming enterprises in Ukraine will be preserved and developed as an effective and competitive form of production organization in agriculture, because they have advantages in the production of many types of agricultural products. However, the scientist considers a favorable state policy to be a necessary condition for ensuring the effective functioning of farming enterprises, as evidenced by the practice of developed countries in Europe and the USA. Therefore, farming requires finding new approaches to the formation of alternative opportunities for its development with higher financial results of economic activity and competitiveness not only in the domestic, but also in the global market environment [5, p. 78-79].

Famous scientists of the Institute of Agrarian Economy believe that functioning of farming enterprises in the modern competitive environment depends on the chosen development strategy, which, on the one hand, reflects their strengths and weaknesses, the position in the industry, and on the other hand, the structure of the industry, which influences the balance of forces that determine the competition in it [9, p. 218]. At the same time, many researchers link the prospects of the development of organizational and legal forms of agriculture in Ukraine with the terms "innovative economy" and "innovation". That is, from the standpoint of the theory of institutionalism, innovation economy is an economy that leads to innovation product/services and in which business entities and industries develop by constant generation of innovations by innovators transformed from scientific and fundamental developments, ideas for achieving profit and improving the quality of life of society. Thus, innovation is the result of creative activity, and the innovator is aimed at the development and distribution of the latest technologies that bring social and economic effect; introduction of new rules and norms of institutional management, forming a new economic order, a new quality of life in society [7, p. 850].

Thus, the results of scientific research by domestic scientists are significant for modern times, but in the conditions of growing socio-economic uncertainty in Ukraine and its regions, the level of risk in the production and economic activity of farming enterprises is increasing. Therefore, there is an objective need to conduct additional applied research, in particular, regarding the analysis of resource provision for the competitive development of farming enterprises in Lviv region, substantiating the prospective directions of their activities, developing appropriate measures that would allow them to strengthen their positions on the market.

## MATERIALS AND METHODS

The purpose of the study is to assess the current state of resource provision for the competitive development of farming enterprises in Lviv region, to determine directions for its formation and effective use.

In the process of research, a number of general scientific and special methods were applied. In particular, the peculiarities of the development of farming were investigated using historical and theoretical methods of knowledge; monographical method - when processing literary sources; abstract-logical and dialectical methods - when clarifying the conceptual apparatus regarding the competitiveness of farming enterprises in the process of studying publications, new and already achieved practical results, formulating conclusions; statistical method – when calculating average values of indicators, deviations, growth rates and increase in resource provision of farmers; methods of mathematical statistics – when assessing the state of development of farming enterprises, carrying out correlation-regression analysis; strategic analysis - when substantiating the conceptual directions of the strategy for the development of farming enterprises of Lviv region in the future.

The information and analytical base of the research was compiled by the State Statistics Service of Ukraine, the Main Department of Statistics in Lviv region, scientific literature on the subject of research, statistical reports of farming enterprises in Lviv region, the results of own research.

## RESULTS AND DISCUSSIONS

Farming enterprises are an important component of the agricultural sector of the Lviv region's economy. In today's conditions, they contribute to ensuring public needs in agricultural products, increasing the efficiency of the use of natural, human and capital resources while preserving the environment, improving the quality of life of the rural population, forming investment and innovation zones and solving social problems of the village. One of the strengths of farming enterprises is their sustainability. All of them operate under conditions of risk and uncertainty, but retain their structure, function and self-identity. As a result of long-term institutional changes in the economy of the state, farming enterprises became the dominant form of business in the agrarian sector of the region (Table 1).

Basing of the made calculation we can see that during 2010-2020 the number of enterprises in the agriculture of Lviv region, which are reported on the operational reports, decreased by 8.4%, including farming enterprises – by 17.7%. In addition, the share of farming enterprises in the structure of enterprises in 2020 was 59.5%.

Table 1. Dynamics and structure of forms of management in agriculture of Lviv region

| Forms of farming | 2010 | | 2015 | | 2018 | | 2020 | |
|---|---|---|---|---|---|---|---|---|
| | Total, units | % | Total, units | % | Total, units | % | Total, units | % |
| Farming companies | 250 | 17.3 | 224 | 15.7 | 357 | 25.7 | 338 | 25.6 |
| Private enterprises | 177 | 12.3 | 128 | 9.0 | 173 | 12.5 | 134 | 10.2 |
| Agricultural cooperatives | 13 | 0.9 | 16 | 1.1 | 38 | 2.7 | 40 | 3.0 |
| Farming enterprises | 956 | 66.2 | 1,044 | 73.1 | 792 | 57.2 | 787 | 59.5 |
| State enterprises | 10 | 0.7 | 6 | 0.4 | 9 | 0.6 | 7 | 0.5 |
| Other enterprises | 38 | 2.6 | 10 | 0.7 | 18 | 1.3 | 16 | 1.2 |
| Total | 1,444 | 100 | 1,428 | 100 | 1,387 | 100 | 1,322 | 100 |

Source: Calculated by author based on [1, p. 67; 2, p. 163].

The dynamics and peculiarities of resource provision of farming enterprises in Lviv region are presented in Table 2.

As the table shows, the number of farming enterprises are decreasing annually and in the reporting year 2020 made up 787 units. The number of employees during the researched period similarly decreased by 18.2%. At the same time, the area of agricultural lands has increased significantly during 2010-2020, namely by 42.5%, including per one enterprise – by 73%. This trend indicates the consolidation of farming enterprises in Lviv region. However, the area of agricultural lands in most enterprises remains less than 100 hectares. Such small farming enterprises have limited opportunities to introduce modern technologies, scientifically based crop rotation, investment projects, etc. However, they can achieve efficiency in soil farming, in growing of perennial crops, vegetable growing, and livestock farming.

The basis of the technical and technological base of farming enterprises is the tools of labor – tractors, agricultural machines, equipment, etc. The scale of use of labor items depends on the level of technology development - seeds, fertilizers, plant and animal protection products, fuel, various types of raw materials and energy resources, fodder, and auxiliary materials. At the same time, technical support of farming enterprises in Lviv region requires a system update.

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Table 2. Resource provision of farming enterprises in Lviv region

| Indicator | 2010 | 2013 | 2015 | 2018 | 2020 | 2020 as compared to 2010, % |
|---|---|---|---|---|---|---|
| Number of farming enterprises, units | 956 | 1,025 | 1,044 | 792 | 787 | 82.3 |
| Area of agricultural lands, ha | 52,066 | 52,306 | 52,348 | 65,900 | 74,200 | 1,42.5 |
| including: arable land, ha | 47,450 | 49,027 | 48,286 | 61,265 | 68,309 | 1,44.0 |
| per one enterprise, ha | 54.5 | 51.0 | 50.1 | 83.2 | 94.3 | 173.0 |
| Number of employees, persons | 2,392 | 2,540 | 2,340 | 2,031 | 1,956 | 81.8 |
| including hired workers, persons | 1,910 | 1,580 | 1,483 | 1,547 | 1,493 | 78.2 |
| Agricultural products, million UAH | 1,325.1 | 1,377.2 | 1,429.4 | 2,107.8 | 2,497.6 | 188.5 |
| including: per one employee, thousand UAH | 553.9 | 542.2 | 610.9 | 1,037.8 | 1,276.9 | 2,30.5 |
| per 100 ha of agricultural lands, thousand UAH | 2,545.0 | 2,632.9 | 2,730.6 | 3,198.5 | 3,366.0 | 1,32.3 |
| Availability of agricultural machinery at the end of the year, units | | | | | | |
| Tractors | 619 | 904 | 937 | 818 | 854 | 1,38.0 |
| Combines | 281 | 306 | 298 | 247 | 274 | 97.5 |
| Beet harvesting machines | 26 | 12 | 17 | 6 | 6 | 23.1 |
| Seeders | 238 | 285 | 333 | 253 | 263 | 1,10.5 |
| Cultivators | 168 | 299 | 325 | 297 | 316 | 1,88.1 |

Source: Calculated by author based on [1; 2].

For example, in the last ten years among the units of agricultural machinery we have seen only an increase of tractors by 38.0%, and in the case of beet harvesters – a significant reduction – by 76.9%. However, modern conditions of economic activity encourage farmers to introduce new means of production, to change the composition and structure of labor items on the basis of accelerating resource-saving processes and introducing innovative and energy-saving technologies into production. Therefore, the current use of means of production takes place in conditions of their gradual renewal, modernization under the influence of scientific and technical progress. The state takes an active part in solving such issues. Without government support, farmers will not be able to compete in the market. In particular, in 2021 among the regions of Ukraine Lviv region took the third place in the amount of paid grant for the maintenance of cows. This grant was received by 77 farming enterprises for the total amount of 9.6 million UAH.

The Department of Agro-Industrial Development of the Lviv Regional State Administration has developed a comprehensive program of support and development of agriculture in the Lviv region for the period 2021-2025. The program envisages support of farming enterprises, the founders of which are the participants of the Joint Forces Operation in the form of budget subsidies for the unit of cultivated land at the rate of 5,000 UAH for 1 ha. In addition, the Program envisages support of economic entities in the field of organic production, namely: 300 thousand UAH in the form of budget subsida for 1 ha of cultivated land at the rate of 1,000 UAH for 1 ha, but not more than 50 thousand UAH per year, as well as 200 thousand UAH in the form of a partial refund of the cost of organic production certification, but not more than 20 thousand UAH per year. Typical programs provide many directions for support of agriculture in the region, but they are not always available to farmers with a land use area of less than 500 ha. For the most part, such farming enterprises rely only on their own capabilities and resources.

The agricultural production increased by 88.5% in farming enterprises during the period under investigation, which positively influenced the realization of major agricultural products in the region. However, in 2020, this form of management accounted for 10.4% of the structure of agricultural products in Lviv region. More than half of the products produced by farmers (57.3%) are crop products, 42.7% are animal products. In crop production, farming enterprises provided 11.3% of the total production volume of grain and leguminous crops, 2.3% of sugar beets, and 1.2% of vegetable crops. The share of farmers in meat production was 27.3%, wool – 22.2%, eggs – 1.6%, milk – 1.6% (Table 3). We consider that in the future livestock products for farming enterprises in Lviv region will become an important condition for increasing production volumes, improving the efficiency of using all types of resources, and primarily land resources, creating higher added value and profitability of activities.

In modern conditions, the proper level of investment support is necessary for the effective development of farming enterprises in Lviv region, which is an important condition for their development and increasing competitiveness. However, for a potential investor, the main attraction factor is business efficiency and prospects for its development. We will evaluate the level of profitability of production of the main types of agricultural products in the farming enterprises of Lviv region (Figure 1).

Table 3. The share of farming enterprises in Lviv region in the production of agricultural products, %

| Indicator | 2010 | 2013 | 2015 | 2018 | 2020 | Deviation, +/- |
|---|---|---|---|---|---|---|
| Grain and leguminous crops | 11.7 | 7.4 | 7.8 | 10.9 | 11.3 | -0.4 |
| Sugar beets | 13.0 | 3.4 | 3.6 | 5.5 | 2.3 | -10.7 |
| Potato | 0.1 | 0.7 | 0.6 | 0.6 | 0.6 | 0.5 |
| Vegetable crops | 2.0 | 2.2 | 1.8 | 1.8 | 1.2 | -0.8 |
| Fodder maize | 13.3 | 14.2 | 18.9 | 30.4 | 33.3 | 20.0 |
| Meat in live mass | 20.4 | 23.9 | 18.6 | 20.3 | 27.3 | 6.9 |
| Milk | 0.6 | 0.8 | 0.8 | 1.2 | 1.6 | 1.0 |
| Eggs | 4.1 | 3.8 | 3.5 | 2.6 | 1.6 | -2.5 |
| Wool | 8.3 | 2.5 | 2.1 | 27.4 | 22.2 | 13.9 |

Source: Calculated by author based on [1, p. 69-71].

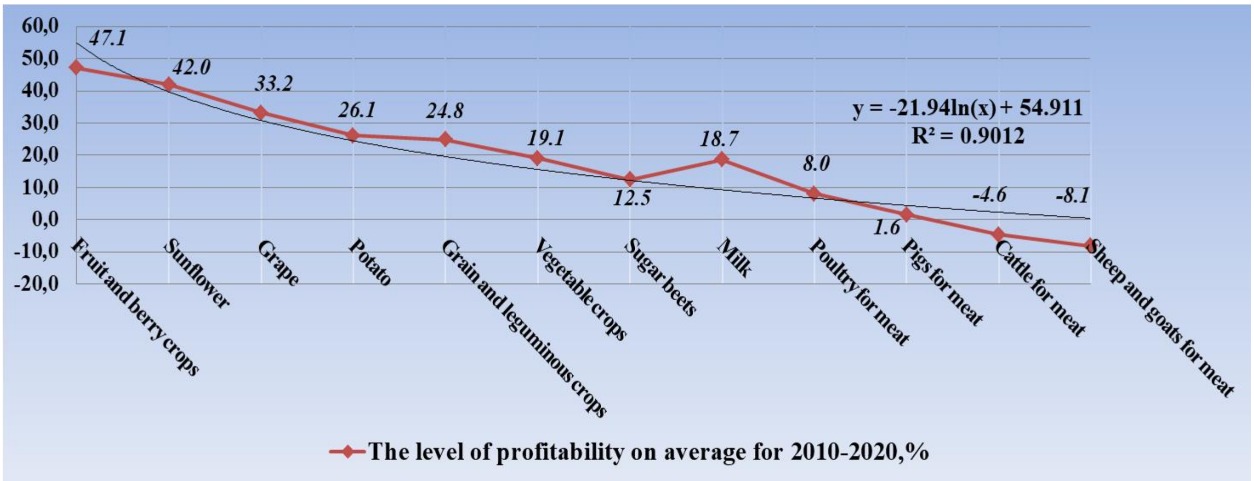


Fig. 1. Investment-attractive agricultural products in the farming enterprises of Lviv region, 2010-2020
Source: Calculated by author based on [1; 2].

Therefore, among the most attractive crop products are fruit and berry crops (the average profitability level for 2010-2020 was 47.1%, including 134.6% in 2020) and sunflower (42.0%). However, in the conditions of armed conflict in Ukraine, the cultivation of grain and leguminous crops deserves special attention. Over the last ten years, the average profitability of these crops was 24.8% in the farming enterprises of Lviv Region, but if necessary and with proper financing, this situation can be improved. Although at the regional level, the cultivation of this type of crops is the prerogative of enterprises with much larger areas of agricultural land, the number of employees, and material and technical support. In the livestock sector, the most attractive for investors is milk production (18.7%). Breeding of cattle for meat, sheep and goats is not profitable. Thus, Lviv region has the best potential for the development of innovative activities, the creation of a favorable business climate, which will make it possible to increase the level of competitiveness of farming enterprises in the region, strengthen their positions on the market, and improve the efficiency of production and economic activities in particular.

Summing up the activity of agricultural producers of Lviv region as a whole, it is expedient to note the positive trends in 2021 as compared to 2020. Thus, the production of crop production in the region increased by 6.0%, livestock production – by 4.6%. The increase in production volumes in the livestock industry occurred as a result of the growth in meat production by 10.4% in the live weight of farm animals sold for slaughter. Similarly, the production of eggs obtained from domestic poultry increased by 3.3%.

In farms of all categories, in 2021 compared to 2020, the number of pigs increased by 18.6%, domestic poultry – by 10.9%, but the number of cattle decreased by 12.3%. The number of cattle as of January 1, 2022 was 126.6 thousand heads (including cows – 76.0 thousand heads), pigs – 430.0 thousand heads, domestic poultry – 11.4 million heads. Such trends in the agrarian sector of the region are the result of a correctly selected strategy for the development of the industry at the state and regional levels. The directions of financial support are constantly being improved, taking into account the needs of economic entities. A special emphasis is placed on supporting farming, which encourages the population to create their own business in the countryside. In the long term, this will slow down the trend of cattle herd reduction in the commercial segment and restore milk production to the level required by the region's milk processing industry. In 2021, more than 278 million UAH was raised from the state and regional budgets to support the farmers of Lviv region, of which almost 43 million UAH was directed to subsidies and partial reimbursement of costs related to the acquisition and maintenance of cattle in agricultural enterprises of Lviv region.

However, the war in Ukraine brought its own corrections and caused numerous losses for the Ukrainian economy. Many previously accepted and worked out strategies for its development have been destroyed. The main attention of the government is focused on the defense complex of the state. Substantial financial support is directed to agriculture and its producers. Thus, in March, the Government made a number of changes to the program "Affordable loans 5-7-9%" for the successful implementation of sowing during the period of martial law. They, in particular, provide for the possibility of receiving preferential loans at 0% annual interest with a guarantee from the Government at the level of 80%. Thus, 13,016 farmers received loans. The following regions are the leaders in crediting: Kirovohrad region (4 billion 81 million UAH), Kyiv region (3 billion 370 million UAH), Vinnytsia region (2 billion 916 million UAH), Dnipropetrovsk region (2 billion 522 million UAH), Odesa region (2 billion 480 million UAH). In addition, more than 1 billion UAH were attracted by Volyn, Lviv, Poltava, Ternopil, Kharkiv, Khmelnytsky, Cherkasy, and Chernihiv regions.

In military conditions and an unstable financial and economic situation in the state farmers are difficult to conduct their economic activity in a profitable manner. It is not always possible to get government support, investments, use modern technologies, withstand growing competition in the market due to a number of subjective and objective factors. Thus, there is an urgent need for the intensive development of agricultural service cooperatives. The actual problem become the expansion of intermediary entrepreneurship, the dependence of farmers on commercial structures, which today act as monopolists in the field of processing and sale of agricultural products, supply of machinery, fuel and lubricants, seeds for the technological process, etc. That is why one of the most successful methods of fighting monopoly of intermediaries in agriculture is the development of service cooperation, through which farmers will be able to solve urgent problems collectively without losing their own independence, that is, their work will be directed directly to solving their own problems. This includes purchasing the necessary material and technical equipment and efficient use of it; processing of own products, its long-term storage and sale; possibility to monitor the situation of the food market, in particular in the EU countries.

## CONCLUSIONS

The farming enterprises of Lviv region have all the prerequisites for development, which depends on the political and economic stability of both the region and the country as a whole. Their strategic development should be focused not only on increasing production volumes, but also on improving the quality of products at optimal production costs, which will ensure a high level of efficiency of their production activities and competitiveness in the domestic and foreign markets. The future of farming enterprises in Lviv region with the obligatory development of organic type of growing vegetables, fruits, berries, potatoes and niche crops while simultaneously restoring the economic efficiency of the livestock industry. All their activities should be based on proven and clear knowledge of the market, consumer demand, assessment of their advantages and disadvantages, taking into account long-term development strategies, provided that the volume of state support increases and the mechanisms for obtaining it are simplified. The economic activity of farming enterprises should become a driving force for the development of rural areas by creating new jobs, industrial and social infrastructure. Thus, the farming enterprises of Lviv region contribute to the employment of broad segments of the population, are distinguished by the effective use of the region's natural resources, saturate the market with the necessary food products and accumulate the growth of tax revenues to the budget, which in wartime conditions is objectively necessary for supporting the economy of the country and the region in particular.

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# EFFICACITY EVALUATION OF SOME ANTI-DRIFT AGENTS IN THE CONDITIONS OF CARACAL PLAIN, ROMANIA

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***Abstract***

*The increasing use of pesticides in modern agriculture has led to increased concerns about the risk of pollution of surface waters, soil and its agro-productive properties. The application of large doses of pesticides using outdated technologies and non-performing agricultural equipments, with poor application in terms of distribution uniformity and the lack of farmers' knowledge and measures to prevent the drift phenomenon leads to their spread outside the targeted areas and implicitly to the increase of environmental pollution. In the present study, three anti-drift agents: EM260 (dodecilbenzensulfonat of calcium 50%, and butanol 18%), SC (heptametiltrisiloxan polietilenglicol) and respectively SO (surfactant non – ionic) have been tested according to ISO 22866, in the field conditions of Agricultural Research Development Station (ARDS) Caracal, Romania. The obtained results emphasized that the most valuable, among all variants, was EM260 (dodecilbenzensulfonat of calcium 50%, and butanol 18%) with smaller drift effect recorded at 1 meter distance (6.4%), followed by the second point, at 3 meters (3.1%) and at 5 meters with a calculated value of 2.1%. Also, at this variant the affected plants percent was smallest from the entire tested assortment, of 35.2%.*

***Key words*: *drift, anti-drift agents, droplet size, crop protection, affected plants***

## INTRODUCTION

The drift phenomenon refers to the floating in the atmosphere and the random movement (carried by the wind) of microparticles of the solution outside the target area when applying different pesticides. It can affect the effectiveness of the treatment itself, due to the fact that a smaller amount of solution reaches the target than the recommended dose, the health of people and animals, due to the penetration of toxic chemicals into inhabited areas near agricultural lands, in the habitat of wild animals, it can affect bees, surface waters and aquatic animals and also it can destroy neighboring crops in the field. By understanding the effects of drift and the factors that influence it, necessary measures can be taken to reduce it.

Spray drift is an inescapable consequence of agricultural plant protection operation, which has always been one of the major concerns in the spray application industry. Spray drift evaluation is essential to provide a basis for the rational selection of spray technique and working surroundings [13].

The reduction of drift is a concern both for environmental organizations and local communities as well, also for industry and agriculture. That is the reason why many specialists in these fields are engaged in a research work to find solutions in order to minimize its effects.

In the obvious climate changes the main issue worldwide proves to be the ability to provide food for billions of people using the resources from agriculture across the planet, ensuring health of plants, animals and people [9][14][16]. The new climate conditions, with higher temperatures and unevenly distributed rains, often outside the period of plant growth and fruiting, or with extreme weather events leads to reconsider the crops technologies, to create new genotypes with higher traits for pests and diseases resistance [3].

In the literature there are lots of studies related to the factors which can influence the drift phenomenon. The majority refers, with higher frequency, to: nozzle type, hole size, nozzle orientation during spraying, viscosity of the emulsion, pression in equipment, temperature and wind speed. Also, it can be mentioned the interactions between equipment, application methods, and spray mixtures, which is fundamental to optimize the application of pesticides. The determination of the best combination of these factors can reduce the drift during the application of treatment solutions [8]. The use of surfactant adjuvant must be carried out carefully, according to the nozzle model, working pressure, and spray mixture. The conventional single fan jet nozzle is more sensitive to increased working pressure and has a high potential to cause drift compared with the models with air induction [8].

The control of droplet spectrum can ensure a successful application of the agrochemical's solutions for various crops. In order to obtain a percentage of the volume of droplets smaller than 100 μm it is recommended the use of spray nozzle with the diameter of the favorable volumetric median for the solutions application leading to a safety anti-drift effect and to more homogeneous droplet spectrum. Adding adjuvants has lower risk of drift, and the increased concentration of adjuvants increase the homogeneity of the droplet spectrum [12, 4].

In the last years, on international market new drift control adjuvants were selected for drift studies in aerial applications. For those conditions, the deposition, droplet size, droplet coverage, and total drops were highly correlated to the drift distance and treatments or adjuvants [10].

The viscosity of emulsions is influenced by the ratio of water/oil. In case of rotary atomizers used for aerial applications, such as forest pest spraying and mosquito control sprays a higher viscosity of emulsion is needed. These types of atomizers have a rotating fan at speeds of 2,000 to 10,000 revolutions per minute (rpm) through which a spray is emitted and atomized. Many applicators routinely add spray adjuvants to change the droplet size, to reduce drift potential, or to reduce evaporative effects of a particular spray solution. For applicators working under hot, dry conditions where evaporation is a concern, choosing an oil-based adjuvant to help get better coverage by creating smaller droplets that do not evaporate, would be recommended [8].

## MATERIALS AND METHODS

In order to evaluate the behavior of three anti-drift agents and direct drift of the pesticides on the field crops, a trial has been established in the experimental field at Agricultural Research Development Station (ARDS) Caracal from the University of Craiova. The tests were applied at wheat crop and included four variants using glyphosate herbicide solutions alone as well as in combination with anti-drift agents. Following the compatibility and stability tests carried out in the laboratory, three of the five identified agents - EM260 (dodecilbenzensulfonat of calcium 50%, butanol 18%), SC (heptametiltrisiloxan polietilenglicol) and respectively SO (surfactant non – ionic) were selected and retained for the field tests. Each of the tested variants consisted of a treatment zone and a measuring zone, adjacent to the treatment zone. According to ISO 22866, the area sprayed directly must be at least 20 m wide from the edge of the application area and the length of the spray track must be at least twice as long as the sampling distance in the transverse direction of the wind and must be symmetrical about the axis of the measuring area. Therefore, each test was performed over a spray distance of 40 m to treat an area of 800 $m^2$ (40 × 20 m) (Figures 1 and 2).

All variants were treated with glyphosate solution (dose of 3 l/ha) in 200 liters of water, in which the anti-drift agents EM260, SC and SO were added. The control variant (APG) was established without any anti-drift agent. Three repetitions were performed for each of the variants. The location of the measuring points was determined starting with half the space between the nozzles compared to the last nozzle of the application installation.

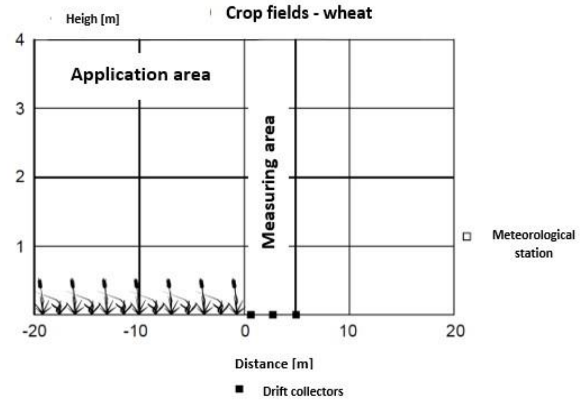

Fig. 1. Application and measuring areas scheme
Source: own experimental design.

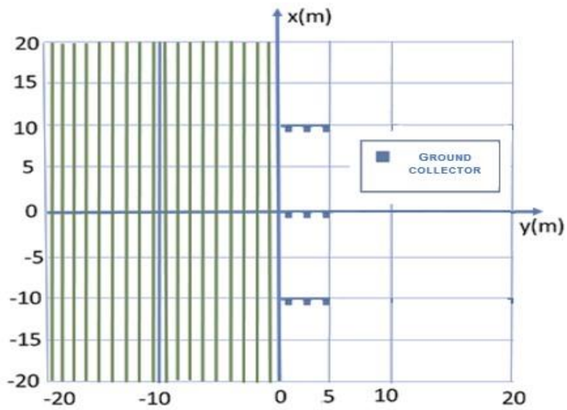

Fig. 2. Ground collectors' positions
Source: own experimental design.

In this study, to assess the risk of field drift, only one type of Lechler ST 110-04 flatbed nozzle was tested at a pressure of 3.0 bar at a flow rate of 1.6 l/minute (Figure 3).


Fig. 3. Lechler ST 110-04 flatbed nozzle
Source: https://www.lechler.com [11].

In order to ensure the application of 200 l/ha, the movement was made with a speed of 10 km/h.
The reference/control application APG was established as the application with the horizontal ramp spray system with flat nozzles with flattened jets standard ISO 04, without air support/induction, with a spray ramp height and nozzle distance of 0.50 m, at a pressure of 3.0 bar and a speed of 10 km/h, resulting an application dose of 200 l/ha. This control application was used for a comparative assessment of the different applications with anti-drift agents. The measurements were performed according to ISO 28666 (2005).
Many studies focused on the efficacy of different types of nozzles pressure on the total reduction potential of drift PRD were made and some obtained data were presented in Table 1.

Table 1. Efficacy of various nozzle types

| Nozzle | ISO nozzle size | $DRP_t$ (%) average | SD |
|---|---|---|---|
| F | 02 | -136.5 | *83.3* |
| $F^S$ | 03 | 0 | *0* |
| F | 04 | 33.9 | *20.8* |
| F | 06 | 29.5 | *6.0* |
| LD | 02 | -3.6 | *56.2* |
| LD | 03 | 38.4 | *11.9* |
| LD | 04 | 54.9 | *15.4* |
| Injet | 02 | 67.2 | *9.7* |
| Injet | 03 | 89.8 | *3.8* |
| Injet | 04 | 77.7 | *4.3* |

Reference spray application; DRPt, Total drift reduction potential
Source: Nuyttens et al. (2008) [15].

During the tests, the following data were recorded (in the area behind the test area, 2 meters above the ground): wind direction (one measured value per second); wind speed (one measured value per second); air temperature (one value measured per displacement); relative humidity (one value measured on the move). The recordings were made with Habotest HT625B digital multimeter meter and correlated with the data obtained from the weather station from experimental fields of ARDS Caracal.
For this research, in each test variant, were evaluated the drops deposited on collectors placed horizontally on the ground at different distances from the edge of the application surface, respectively 1; 3; 5 m were measured.
The experiments were arranged for three repetitions for each variant. The collectors consisted of pieces of wood on which were placed water-sensitive papers measuring 52 x 76 mm (an area of 39.5 square cm).
Water-sensitive paper is a special paper, of different sizes, treated with a substance that changes color in contact with liquids. It is used to assess the degree of products coverage of the target surface when carrying out phytosanitary treatments. Special papers

were subsequently scanned and processed using the DepositScan/ImageJ program.
In order to determine the negative impact of the drift on crop plants, measurements of the number of plants affected by glyphosate were performed using the metric frame.

## RESULTS AND DISCUSSIONS

Spray drift to unintended areas is more of a concern as applications of nonselective herbicides associated with herbicide-resistant crops and the proximity of residential land to agricultural land increase [19]. Without the use of anti-drift agents, the application of foliar fertilizers, herbicides and pesticides would generally be ineffective, firstly because of the inadequate treatment of the crops and secondly because of the unwanted effects on other collateral crops, on the soil and waters. The tests carried out indicated that, in some cases, the anti-drift agents determined the reduction of the drift effect with values between 50-80%. [2][5][20].
Spraying disperses the liquid into droplets of small diameter, the average diameter of the resulting droplets can be very different, from a few microns (µm) to 2-3 mm [10]. Depending on the average droplet size, the following forms (categories) of spraying liquid dispersion are distinguished: atomization, fine spraying, sprinkling and (artificial) rain (Figure 4).

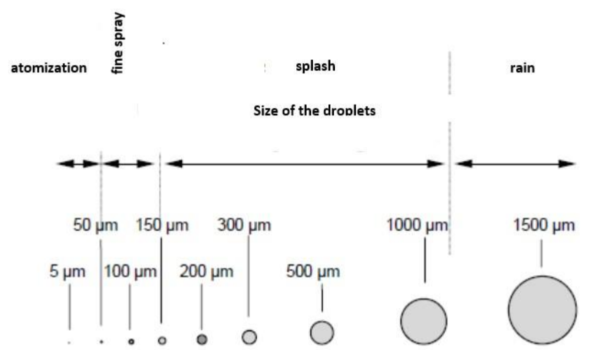


Fig. 4. Classification of forms of spraying (dispersion) of the sprayed liquid according to the size of the drops
Source: Stahli W. & Bungescu T.S. (2006) [18].

Current spraying machines produce drops with diameters between 50 µm and 1.5-2 mm. The size of the drops used depends on the treatment applied and the product sprayed. Thus, for the works to combat cryptogamic diseases, drops with a small diameter are mainly used, and the application of fungicides is usually done by fine spraying. For the rest of the control products and depending on the toxicity of the product for the environment, it is recommended to spray with drops with diameters between 150 and 600 µm. [5][6][17].
In the agricultural sprays more importance is generally given to the pesticide and less to the application technique, though the losses can overpass 70%. The high temperature and the low relative humidity of the air have important effects on the spraying of pesticides, causing faster evaporation of the drops [1].
In the present experiment, the data from table 1 show that the main climatic conditions recorded on 10 repetitions during the test, the wind ranged between 3.57 m/s at variant APG+SC to 4.60 m/s at variant APG (Table 2). Also, the temperature raises from 10.5$^{o}$C when the control variant (APG) was tested to 13.5$^{o}$C at variant APG+SO.

Table 2. Climatic conditions during the test in the experimental fields

| Sample/test | Number of records | Wind Speed (m/s) | Temp. ($^{0}$C) | Relative humidity (%) | Dominant wind direction |
|---|---|---|---|---|---|
| APG | 10 | 4.60 | 10.5 | 84.2 | E/NE |
| APG+EM260 | 10 | 3.97 | 11.0 | 82.8 | E/NE |
| APG+SC | 10 | 3.57 | 13.3 | 71.4 | NE |
| APG+SO | 10 | 3.92 | 13.5 | 70.0 | NE |

Source: own records.

An inverse relationship is observed between temperature and relative humidity of the air. At the beginning of tests, the air humidity was 84.2% (APG variant) and at the end of tests the recorded value was 70.0% in the conditions of increase of the temperature (APG+SO).
It was taken into consideration the dominant wind directions during the tests and the main values shows us that the E/NE was dominant when we applied APG and APG+EM260 and NE direction when we tested the other two variants: APG+SC and APG+SO.
In accordance with the testing procedure, the collectors on the ground – with sensitive

papers samples - were positioned at different distances from the edge of the application surface, respectively 1; 3; 5 m.

After the herbicide application, the sensitive papers were collected and analyzed in order to establish the drift effect by the surface covered by droplets related to the entire surface of the paper sample (Figures 5, 6, 7 and 8).

At the first variant (APG) the dispersion of the droplets (Figure 5) was obvious different was different at the three distances tested. The larger droplets were recorded at 1 meter distance, followed by medium large and medium size on second distance of 3 meter and those with smaller size on the third distance of 5 meter. The calculated values for drift percentage, as average on the three repetitions, were 14.2% at 1 meter, 7.9% for 3 meters distance and 5.2% in case of the 5 meters distance (Table 3).

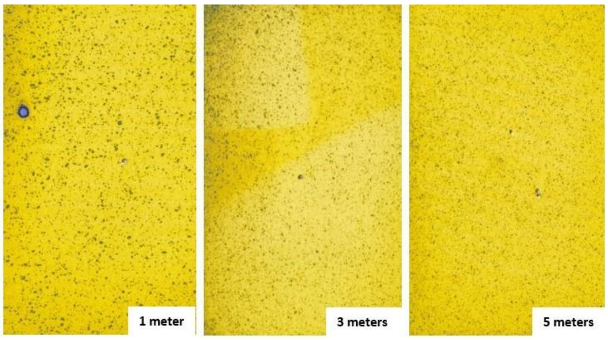


Fig. 5. Images of the water sensitive papers with drop deposits when herbicide glyphosate is applied (APG)
Source: own records.

At the second variant (APG+EM260) we obtained the most valuable results which put us in the position to considerate the EM260 anti-drift agent as the best of the tested assortment. The combination of APG with dodecilbenzensulfonat of calcium 50% and butanol 18% conduct to modified droplet sizes, those with larger size (which represent a large percent of total droplets) were observed on the sensitive paper of ground collector placed at 1 meter from application area (Figure 6). For this point we calculated a value of drift phenomenon of 6.4% (Table 3). On the other two point placed at 3 and respectively 5 meters the values of drift were 2.9% and 1.8%.

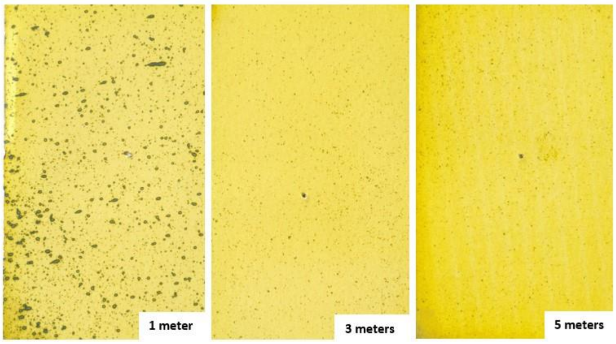


Fig. 6. Images of the water sensitive papers with drop deposits when herbicide is applied with EM260 agent (APG+EM260)
Source: own records.

In case of the third variant (APG+SC), the combination of glyphosate with heptamethyltrisiloxane, polietilenglicol had a favorable influence in order to reduce the drift phenomenon. The uniformity of the distribution of the drops is higher (Figure 7), and the amplitudes between of the values of distances of point recorded in Table 3 certify this.

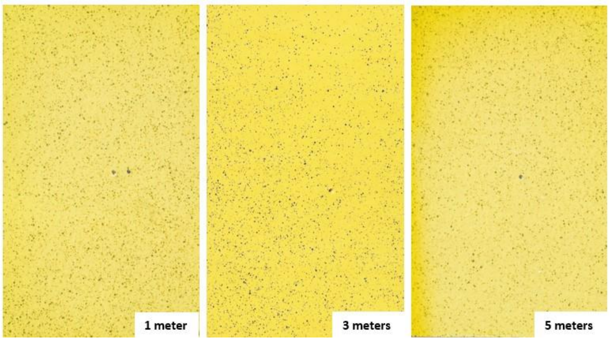


Fig. 7. Images of the water sensitive papers with drop deposits when herbicide is applied with SC agent (APG+SC)
Source: own records.

At 1 meter point, the calculated drift was of 7.6%. For the second point, at 3 meters, we were determinate a drift of 4.3%. On the last point, at 5 meters from the application area, the value of the calculated drift was of 3.1%. This variant, due the results obtained, was appreciated as worst of all in order to reduce de drift phenomenon.

The last tested variant, APG+SO (Figure 9) had almost a similar behavior as previous one, but the values of drift were smaller that the precedent one (Table 3).

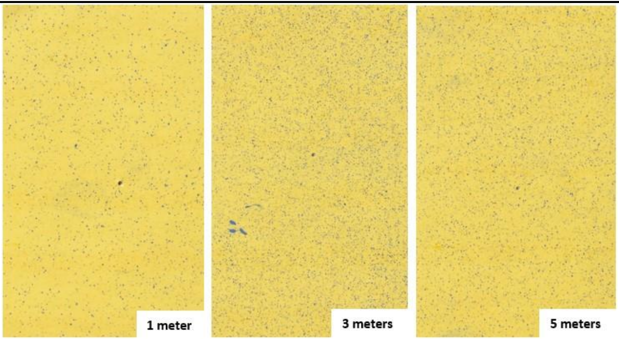


Fig. 8. Images of the water sensitive papers with drop deposits when herbicide is applied with SO agent (APG+SO)
Source: own records.

The non – ionic surfactant used as anti-drift agent prove to be a good solution for decreasing the risks of the uncontrolled spread of pesticide in agricultural practices. Droplet spectrum is also with small differences between ground points of observation. The higher value of drift was recorded at 1 meter distance, with 6.4%, followed by the second point, at 3 meters, with 3.1% and last of the positions, at 5 meters, with a calculated value of 2.1%.

Table 3. The percentage of drift registered on water sensitive papers at tested variants (%)

| Number/ anti-drift agent | Distance | Number of plants/sqm | Number of affected plants | Percentage of affected plants (%) |
|---|---|---|---|---|
| APG | 1 m | 327.0 | 277.0 | 85.0 |
| | 3 m | 363.0 | 288.0 | 79.0 |
| | 5 m | 389.0 | 281.0 | 73.0 |
| APG + EM260 | 1 m | 425.7 | 232.7 | 54.5 |
| | 3 m | 424.7 | 206.0 | 48.7 |
| | 5 m | 449.0 | 158.7 | 35.2 |
| APG + SC | 1 m | 410.0 | 248.7 | 60.7 |
| | 3 m | 460.3 | 260.7 | 56.9 |
| | 5 m | 418.7 | 200.7 | 48.2 |
| APG + SO | 1 m | 462.7 | 260.7 | 56.3 |
| | 3 m | 456.7 | 230.0 | 50.3 |
| | 5 m | 402.0 | 163.3 | 40.6 |

Source: own calculations.

Not only the technical aspect of the experiment was important, but also the practical one. For this reason, we made some field determinations in order to evaluate the percent of the affected plants after the tests were done. All the observation were made at 15 days after application using the square meter frame (Photo 1).
There were determined the number of plants/square meter in the application area, the number of affected plants due the drift phenomenon and based on those values was calculated the percentage of the affected plants (Table 4).

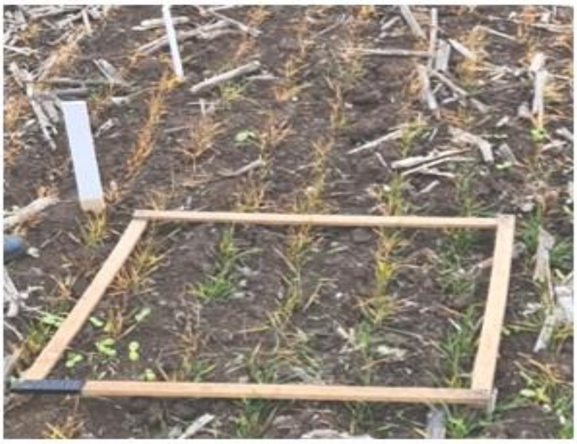

Photo 1. Fields aspect from the determinations of affected plants by experimented variants
Source: own records.

Table 4. Comparative drift measurements using the metric frame by determining the number of the herbicide affected plants with glyphosate alone and with anti-drift agents

| Type / Distance | | R1 % Drops | R2 % Drops | R3 % Drops | Average |
|---|---|---|---|---|---|
| APG | 1m | 14.3 | 13.4 | 15.0 | 14.2 |
| | 3m | 8.6 | 7.1 | 8.0 | 7.9 |
| | 5m | 7.5 | 4.6 | 3.5 | 5.2 |
| APG + EM 260 | 1m | 8.5 | 4.6 | 6.2 | 6.4 |
| | 3m | 4.0 | 2.1 | 2.8 | 2.9 |
| | 5m | 2.0 | 1.6 | 1.7 | 1.8 |
| APG + SC | 1m | 7.8 | 7.3 | 7.8 | 7.6 |
| | 3m | 4.3 | 4.1 | 4.5 | 4.3 |
| | 5m | 3.8 | 2.7 | 2.9 | 3.1 |
| APG + SC | 1m | 6.4 | 6.6 | 6.3 | 6.4 |
| | 3m | 3.0 | 3.3 | 2.9 | 3.1 |
| | 5m | 2.2 | 1.5 | 2.8 | 2.1 |

Source: own calculations.

As it can be observed, the damage caused by the direct action of glyphosate herbicide drift had different values due the treatment/variant tested. The highest percentage of the affected plants has been recorded at variant APG where the glyphosate was applied alone. The percent varied starting 85% at 1 meter point to 79% at the second recorded point at distance of 3 meter and the last values of 73% has been calculated at the point placed at 5 meters distance.
The trend line of decreasing values from first point (1meter) to last point (5 meters) has been registered also to the other variants, but the calculated values were smaller that the control. Thus, on the second variant, where we applied glyphosate with EM260 anti-drift

agent, the percent of affected plants was the smallest from the entire experiment and varied between 54.5% at distance of 1 meter to 35.2% at 5 meters distance. In comparison with the control variant the decrease is more than 30% in case of the distance of 1 meter ground collector and 24.3% in case of the 5 meters distance. This aspect can be observed also in Figure 9 where all the tested variants were compared between them selves.

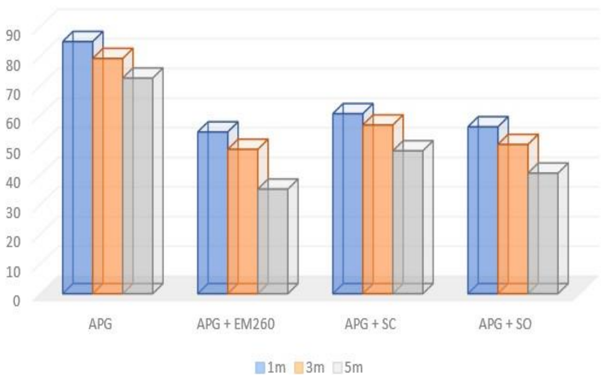


Fig. 9. Drift evaluation of herbicide treatments with anti-drift agents
Source: own calculations.

The last two variants, APG+SC and APG+SO, had closer values of the affected plants, range between 60.7% and 40.2% in case of APG+SC and 56.3% and 40.6% for the APG+SO variant.

## CONCLUSIONS

All over the world there is a large interest about the prevention of drift generated by the application of pesticides to protect the environment. Mitigation of risk arising from spray drift in Europe is achieved mostly by implementation of no-spray buffer zones and the use of approved drift-reducing techniques. Developed country, such Belgium, adopted their own strategy for drift mitigation. In their legislation there is a mainly consists of a classification list of spray nozzles, air assistance and shielded systems are also considered. Also, in Germany, England, the Netherlands and Sweden were adopted specific measures in order to reduce the pollution of surface waters by spray drift in field crops and orchards.

It is all known that the physicochemical properties of spray solutions have a powerful influence to spray drift and they are not yet incorporated into regulatory risk assessments at the European level. The most common solutions to combat the phenomenon of drift remain the use of anti-drift agents or the use of specific nozzles.

Related the tested anti-drift agents in the present experiment it was highlighted the combination of APG+EM260 applied with type of Lechler ST 110-04 flatbed nozzle at a pressure of 3.0 bar and at a flow rate of 1.6 l/minute which had the most valuable results regarding the smallest drift percent and the lowest percent of affected plants. Good practical results were recorded also in combination of APG+SO, variant which have surfactant non – ionic as anti-drift agent.

## ACKNOWLEDGEMENTS

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# SOME ASPECTS REGARDING THE EFFICIENCY OF THE ACTIVITY AT S.C. LUZARDO PREST SERV L.L.C. BÂRCA, DOLJ COUNTY, ROMANIA

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***Abstract***

*S. C. LuzardoPrestServL. L. C. is an economic agent with a considerable seniority in the field (founded in 2009), which appeared in the idea of satisfying the local requirements, related to the needs of the landowners regarding the execution of mechanical works in the agricultural field. In the course of time according to the Articles of Incorporation and due to the evolution of the economic environment, the company has achieved the diversification of its activity by focusing on the cultivation of field plants. The vast majority of the current activity is carried out on the territory of Bârca and Giurgița communes in Dolj County. During the period 2018-2020, the unit cultivated autumn wheat, barley, oats, corn, sunflower and alfalfa.The works follows the situation and the evolution of the financial indicators, starting from the profit and loss account of the unit. The economic operator recorded total revenues between 3,839,945 and 4,058,383 lei (2018 and 2020 respectively), variable total expenses from 3,022,907 lei in 2018 to 3,987,541 in 2020, and the net profit rate reached extremes of 0.97 and 26.05% in the case of the years 2020 and 2018. At the unit level, there is a need for an adequate management of inputs, as well as a more careful reporting on market realities in order to be able to cope with the current economic situation.*

***Key words*****:***expenses, profit, price, income, variation*

## INTRODUCTION

The commercial company LuzardoPrestServ L.L.C., was established as a limited liability company with a single associate, acquiring legal personality on the date of registration at the Trade Register Office attached to the Dolj Tribunal (CUI - 26299144, registration no. - J16/1565/2009) [6].

The registered office of the company is in Bârca commune, Bârca north section, str. Târgului, nr. 72A, Dolj County. The duration of operation of the company is unlimited.

In the articles of incorporation of the company [9] it is mentioned that the main field of activity is classified under CAEN code 0161 – "Ancillary activities for crop production".In addition to the main field of activity, the company can also carry out other secondary activities in the fields of agriculture, hunting and related services; fisheries and aquaculture; food industry; manufacture of beverages; the manufacture of tobacco products; wholesale and retail trade - excluding motor vehicles and motorcycles; rental and leasing activities, etc.The articles of incorporation also contain information relating to the management of the company, control of the company, bank account, calculation and payment of benefits, financial year, dissolution and liquidation of the company, disputes.

At the moment, the company works 700 ha which are located in the area of Bârca and Giurgița communes. Society practices a range of crops, quite varied (which gives it the possibility of practicing an adequate rotation): autumn wheat, barley, oats, corn, sunflower, alfalfa.The crops presented above (e.g. maize) are distinguished by their multiple uses (including ensuring food security) and can be as sources of profit [2, 3]. The cereal crops practiced (about 75% of the area, at the unit level) come and reinforce the idea that they represent the main source of income of the agricultural producers in our country [4].

The company has multiple facilities, materialized in fixed capital elements, as follows: 8 tractors (Case IH, DeutzFahr 9340 TTV, Europard, Jhon Deere 6900, New Holland T 7260 CL, New Holland T 6175 - 2 pieces, backhoe loader), 7 plows (Huards Kuhn, KvernelandVario, Kverneland-reversible, Kverneland PG 1008 - 2 pieces, Gregoire et Besson, Quivogne Aster 120), 2 fertilizing machines (Kuhn - 2 pieces), 4 harrows (Diskator 610, Kverneland, Rabewerk - 2 pieces), 6 sowers (peas - 2 pieces, Kuhn - 2 pieces, Kverneland Optima, SPC 8), 2 cultivators (Bendar, Horsch Tiger), 2 mills, 2 machines for carrying out treatments, irrigation plants, 2 combines and specific harvesting equipment (Case AF 6088, Laverda M 200, corn picker - 2 pieces, specific equipment for straw cereals, rapeseed, sunflower), mowers - FPM Agromehanika, 1 baler - Maschio, 1 baler balers - Pomarol, 1 wrapping machine - Vicon,8 trailers (various types), administrative buildings and associated with the productive process (administrative headquarters, warehouses, warehouses, video surveillance system, mechanical workshop, service station, drainage system, underground irrigation system), 4 loading equipment, various equipment (GPS systems, crane, wheat mill, lathe), 3 cars, 3 trucks, etc.. The inventory value of the capital, at the end of 2020, was 8,754,755.44 lei [11].

Income express saleable value of goods and services produced in a company [14]. Agricultural producers can also benefit from incomes in the form of subsidies, which encourages their positive evolution (volume of inputs attracted, compensation of some expenses, practice of organic crops, etc.) [13]. Revenues are also important in that they influence the lifestyle of producers [1].

Expenditure as an economic category, if a thorough analysis is made, helps the manufacturing sector to adopt a strategy adapted to the specifics of the activity carried out [12].

From the point of view of economic results, it is important to periodically analyse the factors that can influence the size of the profit [8]. The size of the profit is influenced by the level of production capitalised, the value of the cost of production and the selling price obtained in the course of marketing [15].Profit-making can sometimes be a difficult goal for small and medium-sized agricultural producers to achieve, as they have to maintain relations with existing market intermediaries [5]. Profit is a means that ensures the continuity (resumption) of productive activity [7].

## MATERIALS AND METHODS

For the present work – there were determined, according to the recommended methodology, and interpreted indicators, grouped into three categories: **income indicators** – sold production, income from the sale of goods, net turnover (further defined, turnover – resulting from the summation of the first two indicators); income on the current cost of production (caught in the text as revenue for the cost of production), income from operating subsidies, income from other sources, income from other sources of operation (obtained by summing up the components that have been presented above), interest income, other financial income, financial income (resulting from the summation of the two indicators presented above); total income (determined as the sum between operating income and financial income); **spending indicators:** expenditure on raw materials and consumables, other material expenditure, other external expenditure (energy and water), expenditure on goods, trade reductions received, total material and expenditure on goods (resulting from the summation of previous indicators); salaries, insurance costs, staff costs (determined as the sum between salaries and insurance costs); adjustments relating to tangible and intangible assets (hereinafter referred to as adjustments relating to assets); expenditure on external benefits, expenditure on other taxes, duties and similar payments (hereinafter referred to as expenditure on other taxes and charges), other charges, other operating charges (resulting from the summation of the last three indicators referred to above); total operating expenses (the sum of material and expenditure on goods, personnel costs, adjustments to fixed assets and other operating charges); expenditure on interest, other financial charges, total financial expenditure (determined by summing up the last two indicators presented above); total expenditure (resulting from the summation of operating expenses and financial charges); **profitability indicators:** profit or loss on operation, profit or loss, profit or gross loss (sum of the two indicators presented above); corporate tax, other taxes or duties, net profit or loss (difference between gross profit or loss and the amount of tax and other taxes or duties); rate of profit or loss on the operation (percentage ratio between operating profit or loss and operating expenses), the rate of financial profit or loss (percentage ratio of financial profit or loss to financial expenses); gross profit or loss ratio (percentage ratio of gross profit or loss to total expenses); net profit or loss ratio (percentage ratio of net profit or loss to total expenses).

The essential information source is represented by the Profit and Loss Account of the company [10].

The indicators take the form of a dynamic series consisting of four terms: the years 2018, 2019, 2020 and the average period. The evolution, over time, of the indicators is highlighted by means of fixed base indices.

## RESULTS AND DISCUSSIONS

Table 1 shows the indicators of income for the years 2018, 2019, 2020 and average period.

The value of production was between 2,619,324 lei in 2018 to 3,047,639 lei at the level of 2019, and the average of the period was 2,817,509.33 lei. There is an uneven evolution of the indicator, the increases of 16.35% recorded in 2019 compared to those of 2018, being followed by lower levels in 2019 compared to the composition base (6.35%), and for the average of the period the exceedance of the reporting base was 7.57%.

The revenues from the sale of goods had an average of 85,951.67 lei (+13.34% in dynamics), a value based on sequential levels of 75,832 lei in 2018, 70,889 lei in 2019 (-6.52% in dynamics) and 111,134 lei for 2020 (+46.35% compared to the first term of the dynamic series).

Table 1. Indicators of income (lei)

| No. | Specification | 2018 | 2019 | | 2020 | | Average** | |
|---|---|---|---|---|---|---|---|---|
| | | Ef.* | Ef.* | 2019/ 2018** | Ef.* | 2020/ 2019** | Ef. | Average / 2018 |
| 1. | Production sold | 2,619,324 | 3,047,639 | 116.35 | 2,785,565 | 106.35 | 2,817,509.33 | 107.57 |
| 2 | Revenue from the sale of goods | 75,832 | 70,889 | 93.48 | 111,134 | 146.55 | 85,951.67 | 113.34 |
| 3 | Turnover | 2,695,156 | 3,118,528 | 115.71 | 2,896,699 | 107.48 | 2,903,461.00 | 107.73 |
| 4 | Revenue related to the cost of production | 209,909 | 4,263 | 2.03 | 144,262 | 68.73 | 119,478.00 | 56.92 |
| 5 | Income from operating subsidies | 809,794 | 778,851 | 96.18 | 928,611 | 114.67 | 839,085.33 | 103.62 |
| 6 | Other operating income | 125,066 | 67,997 | 54.37 | 87,052 | 69.60 | 93,371.67 | 74.66 |
| I | Operating income | 3,839,925 | 3,969,639 | 103.38 | 4,056,624 | 105.64 | 3,955,396.00 | 103.01 |
| 7 | Interest income | 20 | -8 | 0 | 94 | 470 times | 35.33 | 176.65 |
| 8 | Other financial income | 0 | 0 | 0 | 1,665 | 100 | 555.00 | 33.33 |
| II | Financial income | 20 | -8 | 0 | 1,759 | 8795 times | 590.33 | 29.51 times |
| III | Total revenue | 3,839,945 | 3,969,631 | 103.38 | 4,058,383 | 105.69 | 3,955,986.33 | 103.02 |

Source: *data extracted from the Profit and Loss Account (2018 – 2020).
** own calculation.

The turnover varied from 2,695,156 lei in 2018 to 3,118,528 lei for 2020, so that the average of the period reached 2,903,461 lei (given that 2020 is characterized by a value of 2,896,699 lei). The dynamics of the indicator contains only supra-unit indices (107.48, 107.73 and 115.71% for 2020, the average of the period and 2019, respectively). The revenues related to the production cost were between 4,263 lei in 2019 and 209,909 lei for 2018, and the average of the period was 119,478 lei (given that at the level of 2020 it was recorded a value of 144,262 lei). As a result, there is an uneven evolution of the indicator.

The income from operating subsidies has an average of839,085.33 lei, with extreme values of 778,851 lei and 928,611 lei, specific to the years 2019 and 2020, respectively. The dynamics of the indicator highlight a fluctuating evolution of the indicator, characterized by a decrease of 3.82% in 2019 compared to the reference term and by its exceedances, by 3.62 and 14.67% respectively, for the average of the period and in the case of 2020.

The manufacturer recorded other operating income in all the analysed years, as follows: 67,997 lei in 2019, 87,052 lei in 2020 and 125,066 lei for 2018. These values determined an average of 93,371.67 lei. The dynamics show a downward-uneven evolution of the indicator, with levels (of the indices) of 54.37, 69.60 and 74.66% in 2019, 2020 and for the average period, respectively.

The unit recorded operating income, which reached levels of: 3,839,925 lei in 2018, 3,969,639 lei for 2019, 4,056,624 lei in 2020 and 3,955,396 lei for the average of the period. The dynamics of the indicator have only supra-unit indices: 103.38% in 2019, 105.64% for 2020 and 103.01% for the average period.

The interest income was 20 lei in 2018, -8 lei for 2019 and 94 lei for 2020, so that the average of the period was 35.33 lei. The dynamics highlight supra-unit values in 2020 and for the average period – 470 and 1.76 times the comparison term, respectively.

During the analysed period, there are other financial incomes only in the case of 2020 (1,665 lei), so that the average of the period represented 33.33% of this level (555 lei).

Financial revenues are characterized by an average of 590.33 lei (29.51 times the comparison base, in dynamics), an average of which is based on annual sequential levels of 20 lei in 2018, -8 lei for 2019 and 1,759 lei for 2020.

Table 2 contains the indicators of expenditures for the period under review.

Table 2. Indicators of spending (lei)

| No. | Specification | 2018 | 2019 | | 2020 | | Average** | |
|---|---|---|---|---|---|---|---|---|
| | | Ef.* | Ef.* | 2019/ 2018** | Ef.* | 2020/ 2018** | Ef. | Average/ 2018 |
| 1 | Expenditure on raw materials and consumables | 1,528,635 | 1,713,960 | 112.12 | 1,806,097 | 118.15 | 1,682,897.33 | 110.09 |
| 2 | Other material charges | 14,169 | 19,090 | 134.73 | 8,592 | 60.64 | 13,950.33 | 98.46 |
| 3 | Other external expenditure (energy and water) | 16,464 | 51,368 | 312.01 | 6,080 | 36.93 | 24,637.33 | 149.64 |
| 4 | Expenditure on goods | 62,837 | 58,855 | 93,66 | 123,193 | 196.05 | 81,628.33 | 129.90 |
| 5 | Trade discounts | 125,612 | 145,349 | 115.71 | 237,001 | 188.68 | 169,320.67 | 134.80 |
| 6 | Material and expenditure on goods | 1,496,493 | 1,697,924 | 113.46 | 1,706,961 | 114.06 | 1,633,792.67 | 109.17 |
| 7 | Salaries | 445,371 | 562,444 | 126.29 | 741,947 | 166.59 | 583,254.00 | 130.96 |
| 8 | Insurance costs | 3,152 | 4,892 | 155.20 | 8,708 | 276.27 | 5,584.00 | 177.16 |
| 9 | Personnel costs | 448,523 | 567,336 | 126.49 | 750,655 | 167.36 | 588,838.00 | 131.28 |
| 10 | Adjustments for fixed assets | 665,937 | 760,313 | 114.17 | 1,021,299 | 153.36 | 815,849.67 | 122.51 |
| 11 | Expenditure on external benefits | 145,393 | 287,655 | 197.85 | 230,688 | 158.67 | 221,245.33 | 152.17 |
| 12 | Expenditure related to other taxes and charges | 120,772 | 36,675 | 30.37 | 29,187 | 24.17 | 62,211.33 | 51.51 |
| 13 | Other expenditure | 61,550 | 35,615 | 57.86 | 31,173 | 50.65 | 42,779.33 | 69.50 |
| 14 | Other operating charges | 327,715 | 359,945 | 109.83 | 291,048 | 88.81 | 326,236.00 | 99.55 |
| I | Total expenditure Exploitation | 2,938,668 | 3,385,518 | 115.21 | 3,769,963 | 128.29 | 3,364,716.33 | 114.50 |
| 15 | Interest expenditure | 83,622 | 164,122 | 196.27 | 205,678 | 245.96 | 151,140.67 | 180.74 |
| 16 | Other financial expenditure | 617 | 8,538 | 13.83 times | 11,900 | 19.28 times | 7,018.33 | 11.37 times |
| II | Financial charges | 84,239 | 172,660 | 204.96 | 217,578 | 258.29 | 158,159.00 | 187.75 |
| III | Total expenditure | 3,022,907 | 3,558,178 | 117.71 | 3,987,541 | 131.91 | 3,522,875.33 | 116.53 |

Source: *data extracted from the Profit and Loss Account (2018 – 2020).
** own calculation.

For raw materials and consumables, values are found from 1,528,635 lei in 2018 to 1,806,097 lei in 2020, the average of the period reaching 1,682,897.33 lei.The dynamics underline the upward trend of the indicator, the advance in 2019 and 2020 (1.12 and 1.18 times compared

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to the first term of the dynamic series) being followed by a more temperate growth for the average period (1.10 times).

Other material expenses appear in all years – 14,169, 19,090 and 8,592 lei respectively, values that determine an average of the period of 1,395.33 lei. The dynamics include values, of the component indices, from 60.64 to 134.73% (years 2020 and 2019, respectively).

The article, other external expenses, is characterized by an average of 24,637.33 lei (149.64% in dynamics), with extremes of 6,080 and 151,368 lei at the level of 2020 and 2019 respectively (36.93 and 312.01% compared to the first term of the dynamic series in 2018 – 16,464 lei).

Expenditures on goods recorded an average of 81,628.33 lei (+29.90% in dynamics), which is based on annual levels of: 62,837 lei in 2018, 58,855 lei for 2019 (-6.34%) and 123,193 lei for 2020 (+96.05% compared to the reporting deadline).

The commercial discounts were of 125,612 lei in 2018, then they increased by 15.71% in 2019 (145,349 lei), an increase that was accentuated in the case of 2020 - +88.68% (237,001 lei). As a result, the average period reached 169,320.67 lei (134.80% in dynamics compared to the reporting base).

Consequently, the total expenditures on materials and goods were between 1,496,493 lei in 2018 and 1,706,961 lei for 2020 (1.14 times increase in dynamics), and in 2019 a value of 1,697,924 lei was reached (1.13 times). In these conditions, the average of the period was of 1,633,792.67 lei, which in dynamics represented an increase of 9.17% compared to the reporting base. The dynamics of the indicator are an upward-uneven one.

Salary expenses recorded an increase from 445,371 lei in 2018, 1.26 times in 2019 (562,444 lei) and 1.66 times in 2020 (741,947 lei). In these conditions, the average of the period was 583,254 lei, representing 130.96%compared to the reference term.

Insurance had an average of 5,584 lei (overshoot of +77.16% compared to the reporting base), with extreme values of 3,152 lei in 2018 and 8,708 lei for 2020 (+176.27%).

Personnel expenses had increasing values, for the analysed period, from 448,523 lei in 2018, to 567,336 lei for 2019 and up to 750,655 lei at the level of 2020, while the average of the period was 588,838 lei. It can be discussed by an upward-uneven trend of the indicator highlighted by the exceedances of the reference term as follows: 1.26 times in 2019, 1.67 times for 2020 and 1.31 times in the case of the average period.

Adjustments on fixed assets have a net upward trend. The year 2018 is characterized by a value of 665,937 lei, which increases to 760,313 lei in 2019, respectively to 1,021,299 lei for 2020. In these conditions, the average period reached 815,849.67 lei (122.51% compared to the reporting base). Dynamics contains strictly super-unit indices (114.17 and 153.36% for 2019 and 2020, respectively).

Expenditures on external services amounted to 145,393 lei in 2018, increased by 97.85% in 2019 (287,655 lei) and by 58.67% for 2020 (230,688 lei), and the average of the period reached 221,245.33 lei (+52.17% in dynamics compared to the reporting deadline).

As for the expenses with other taxes and fees, it can be noted that they varied from 29,187 lei in 2020 to 120,772 lei at the level of 2018, while the average of the period was 62,211.33 lei (given that 2019 presents a level of 36,675 lei). In the created dynamics, only subunit values can be observed: 30.37, 24.17 and 51.51% for 2019, 2020 and for the average period, respectively.

For the other expenses element, the company registers an average of 42,779.33 lei (-30.50% compared to the comparison base), an average of which has as determining values 61,550 lei from 2018, 35,615 lei from 2019 (-42.14% in dynamics) and 31,173 lei registered for 2020 (-49.35%).

Other operating expenses recorded the following situation: 327,715 lei in 2018, 359,945 lei for 2019 and 291,048 lei for 2020. In these conditions, the average of the period was 326,236 lei. Starting from these values, the dynamics of the indicator were constituted, characterized by a single supra-unit value in 2019 (109.83%) and by two subunit levels for 2020 and respectively for the average of the period (88.81 and 99.55%).

The total operating expenses have sequential levels of: 2,938,668 lei in 2018, 3,385,518 lei for 2019 (+15.21% in dynamics), 3,769,963 lei in 2020 (+28.29%), 3,364,716.33 lei in the case of the average period (+14.50%).

The company made interest expenses in all years: 83,622 lei in 2018, 164,122 lei for 2019 (+96.27% in dynamics), 205,678 lei in the case of 2020 (+145.96%). As a result, the average period reached 151,140.67 lei (180.74%).

Other financial expenses appear, with an average of 7,018.33 lei (11.37 times the reporting base is 11.37 times) which was due to the annual sequential levels of 617, 8,538 and 11,900 lei respectively - for 2018, 2019 (13.83 times compared to the previous year) and 2020 (19.28 times compared to the first term of the dynamic series).

This situation determined total financial expenses of 84,239 lei at the level of 2018, 172,660 lei in 2019 (+104.96% in dynamics) and 217,578 lei for 2020 (+158.29% compared to the reference base). As a result, the average of the period was 87.75% higher than the comparison term, reaching a level of 158,159 lei.

Regarding the level of total expenses, it should be noted that it reached 3,022,907 lei in 2018, 3,558,178 lei for 2019 and 3,987,541 lei for 2020, respectively, while the average of the period reaches 3,522,875.33 lei.

The dynamics of the indicator is made up, only, of super-unitary indices – 116.53, 117.71 and 131.91% for the average of the period, 2019 and 2020, respectively.

Table 3 shows the level of profitability indicators.

Table 3. Profitability indicators

| No. | Specification | U.M. | 2018 | 2019 | | 2020 | | Average** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Ef. | Ef. | 2019/ 2018 | Ef. | 2020/ 2018 | Ef. | Average/ 2018 |
| 1 | Operating profit * | lei | 901,257 | 584,121 | 64.81 | 286,661 | 31.81 | 590679,67 | 65.54 |
| 2 | Financial loss * | lei | 84,219 | 172,668 | 205.02 | 215,819 | 256.26 | 157,568.67 | 187.09 |
| 3 | Gross profit * | lei | 817,038 | 411,453 | 50.36 | 70,842 | 8.67 | 433,111.00 | 53.01 |
| 4 | Other taxes or duties * | lei | 29,459 | 36,509 | 123.93 | 32,225 | 109.39 | 32,731.00 | 111.11 |
| 5 | Net profit * | lei | 787,579 | 374,944 | 47.61 | 38,617 | 4.90 | 400,380.00 | 50.84 |
| 6 | Rate of operating profit ** | % | 30.67 | 17.25 | 56.24 | 7.60 | 24.78 | 17.55 | 57.22 |
| 7 | Rate of financial loss ** | % | 99.97 | 100.01 | 100.04 | 99.19 | 99.22 | 99.63 | 99.66 |
| 8 | Gross profit rate ** | % | 27.03 | 11.56 | 42.77 | 1.78 | 6.59 | 12.29 | 45.47 |
| 9 | Net profit rate ** | % | 26.05 | 10.54 | 40.46 | 0.97 | 3.72 | 11.37 | 43.65 |

Source: *data extracted from the Profit and Loss Account (2018 – 2020).
** own calculation.

The operating profit is characterized by an average of 590,679.67 lei, a value resulting from the sequential annual levels of 901,257 lei in 2018, 584,121 lei for 2019 and 286,661 lei specific to 2020. These values highlight the downward trend of the indicator, the decreases compared to the reference period of 35.19% for 2019, 68.19% for 2020 and 34.46% for the average period.

The financial loss was of 84,219 lei in 2018, 172,668 lei at the level of 2019 and of 215,819 lei for 2020 (in dynamics supra unit values of the indices: 205.02 and 256.26% for 2019 and 2020, respectively). As a result of this state of affairs, the average of the period reaches 157,568.67 lei, i.e. 187.09% compared to the reference term.

The gross profit has values of 817,038 lei in 2018, 411,453 lei at the level of 2019, 70,842 lei for 2020 and 433,111 lei for the average period. The dynamics of the indicator is characterized by sub-unit values of the component indices: 50.36, 8.67 and 53.01% for the years 2019, 2020 and, respectively, the average of the period.

The company paid other taxes, but did not pay corporate tax. Thus, values of the indicator are found, as follows: 29,459 lei in 2018, 36,509 at the level of 2019 (+23.93% in dynamics), 32,225 lei in the case of 2020 (+9.39%), 32,731 lei for the average period - level that represented 111.11% of the reporting base.

The net profit is characterized by an average of 400,380 lei, given that the extreme values of the indicator appeared in 2020 – 38,617 lei

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and, respectively, 2018 – 787,579 lei. The dynamics of the indicator is a downward-uneven one, the decreases compared to the reporting term being of 52.39% for 2019, 95.10% for 2020 and 48.16% for the average of the period.

The operating profit rate was 30.67% in 2018, 17.25% in the case of 2019, 7.60% for 2020 and 17.55% for the average of the period. The evolution, over time, of the indicator is in the form of a downward-fluctuating trend, the decreases in 2019 of 43.76%, being followed by other decreases -higher- in 2020 (75.22%), and for the average of this period reached 42.78%.

The company recorded a financial loss rate of 99.63% at the level of the average period, which is based on the rates of 99.97, 100.01 and 99.19% specific to the years 2018, 2019 and 2020, respectively. A fluctuating dynamic was recorded, being characterized by an increase in 2019 compared to 2018 (+0.04%) and two decreases for 2020 respectively for the average of the analyzed period (0.78 and 0.34%).

We can see a lower gross profit rate than that of operating profit (absolutely normal situation, which was determined by the existing financial losses): 27.03% in 2018, 11.56% for 2019 (42.77% in dynamics), 1.78% at the level of 2020. (6.59%), 12.29% for the average of the range (45.47% compared to the reference term).

The net profit rate averaged 11.37%, with extreme values of 0.97% in the case of 2020 and of 26.05% in 2018. As a result of this situation, the dynamics are a downward-uneven one, the reference term being higher by 59.54, 96.28 and 56.35%, than the specific situation for 2019, 2020 and for the average of the period, respectively.

In the structure of total income, operating income predominates with 99.99%, financial income being only 0.01% of the total. The components of operating income are found in proportions of: 2.36% other operating income, 3.02% income related to the cost of production in progress of execution, 21.22% income from operating subsidies, 73.39% net turnover (Fig. 1). Interest income predominates in financial income.

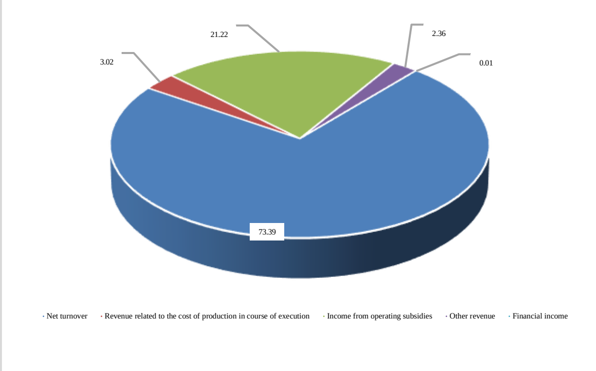


Fig. 1.Total operating income structure (%)
Source: own calculation.

In the structure of total expenses, operating expenses predominate (95.51%), while financial expenses are reduced (4.49%). Among the operating expenses, material and goods expenses predominate – 46.37%, followed by adjustments for tangible and intangible assets – 23.16%, personnel expenses – 16.71% and other operating expenses – 9.27% (Fig. 2).

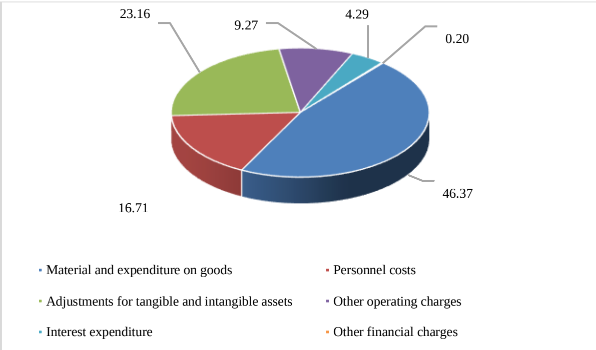


Fig. 2.Total expenditure structure (%)
Source: own calculation.

The components of financial expenses hold, in total, shares of 0.20% of other financial expenses and 4.29% of interest expenses.

The unit registers operating profit, but also financial loss – 590,679.67 and 157,568.67 lei, respectively, which determines a level of 433,111 lei of gross profit. The net profit was 400,380 lei.

With great results, 2018 stands out – as a year of maximum and the year 2020 as a year of minimum.

A better management of expenditure items is needed, but there is also a need for appropriate policies from the state to support the activity of companies in the field of agricultural production.

## CONCLUSIONS

Based on the history of the company, it can be found that it has adequate experience for the activity it carries out.

The decrease in profit, from year to year, is influenced by the specifics of the three years (natural and economic-social conditions). This is also due to the fact that the pace of growth in expenditure is higher than the pace of revenue growth. Also, as an element that negatively influences the level of profit is also manifested financial expenses, this led to the occurrence of losses of this nature at the level of the producer.Based on the experience held and as a result of the trends of the socio-economic environment, it is necessary to manage as carefully as possible the factors of a technological nature, in accordance with the evolution of the pedoclimatic conditions specific to the development of the activity. On this basis, the unit must adequately manage the level of inputs used in the current activity. At the same time, the question arises of a thorough prospecting of the sales market, so as to achieve the capitalization of the products at the most advantageous moments and prices.

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# ASSESSMENT OF FERTILIZATION PLANS ON BASIC CROPS. A CASE STUDY

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***Abstract***

*The most effective way to enrich the food resources necessary for humanity is to increase agricultural production per hectare, which can be achieved by introducing new cultivars and high-performance hybrids, by improving the cultivation technology, by calculating the need for nutrients in each crop, and by taking into account the crop, the expected productions and the natural fertility of the soil. This paper aims at evaluating the fertilization plans made on a farm in the town of Curtici, Arad County, Romania, in the main agricultural crops: wheat, barley, maize, and rape. During an annual vegetation cycle, there are several pheno-phases that are characterized by a differentiated consumption of nutrients, which determines the application of different types and doses of fertilizers. The farm is equipped with a series of tractors and agricultural machines with which they work the 600 ha of land and provides various mechanization services to different physical and legal people in the area. The main activity of the farm is the cultivation of cereals. The identified soils were chernozem, preluvosol and alluviosol, i.e., soils that have good and very good natural fertility. Following the calculations made, it turned out that the nutrient requirements were 57.08 t/ha of nitrogen, 78.33 t/ha of phosphorus and 29.80 t/ha of potassium. In wheat, the largest quantity in nutrients is in nitrogen, which plays an essential role in the growth phase, after which the requirement of nitrogen decreases. The productions obtained were different depending on the year, the climatic conditions and the doses of fertilizers applied: in wheat, 7.5 t/ha in 2020 and 8.0 t/ha in 2021; in grain maize, 8.0 t/ha in 2020 and 8.2 t/ha in 2021, with an average of 8.1 t/ha; in barley, between 8.1 t/ha in 2020 and 8.1 t/ha in 2021; and in rapeseed, 3.5 t/ha in 2020 and 3.6 t/ha in 2021. It was found that the application of fertilizers in the recommended doses depending on the crop, on plant growth phase, and on the plant, needs increases the production in all four crops in the study. In conclusion, the correct establishment of fertilization plans is the most useful tool in establishing the recommended fertilizers, taking into account both the natural fertility of the soils on the farm, of their plants, of their nutritional needs, of the expected productions and of the expenses necessary to purchase the fertilizers (whether organic or mineral fertilizers). Thus, making early economic decisions related to what we need to cultivate, on what surfaces, to the works involve in each crop, to the quantities of necessary fertilizers and treatments helps purchase the necessary products in due time and at better prices. This is how one saves considerable price differences, resulting in lower production costs and higher profits.*

***Key words***: *evaluation, fertilization plan, fertility, productive potential*

## INTRODUCTION

Romania has been among the top 10 producers of maize worldwide since 2018 according to the Food and Agriculture Organization of the United Nations [25] and the most important maize grower within the European Union according to Eurostat [1, 9]. Statistics from the Ministry of Agriculture and Rural Development from Romania indicate that, since the integration in the European Union, both the average yield-per-unit area as well as total production of maize increased at the national level [27], presenting attractive export potential. The possibility to increase exports is relying on the optimization of maize crop performance, in order to ensure high-quantity and -quality maize [14, 6, 26].

To make the most of their productive potential, crops need appropriate water, light, carbon dioxide, and mineral nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, and a number of microelements), the soil being the main source of mineral nutrients and water for plants [2, 3].

The removal of nutrients from the soil by plant absorption, by leisure or by other processes related to the natural dynamics of the soils, result in a decrease of the contents of mobile forms of nutrients and in the gradual decline of the production capacity of the soils [4, 5].This is why it is necessary, as an objective necessity, to compensate, by applying mineral and organic fertilizers, both consumption by the crops and decreased nutrient mobility through natural processes (adsorption, fixation, immobilization in humic substances, etc.) [8].

For both economic and environmental protection reasons, it is necessary to use the correct management and use of the fertilizers at the level of each holding [12]. Awareness of each agricultural producer is required because, in order to achieve large productions, the use of fertilizers must be made on the basis of realistic forecasts, which take into account the soil and climate conditions specific to each area, the productive potential of crops, and the applied technology [13, 15].

A special emphasis, especially in areas with high vulnerability to the pollution of water with nitrates of agricultural origin, should be placed on the management of organic and mineral fertilizers, given the particularly complex behaviour of this nutrient and the ease with which it can be leaked in the form of nitrates by infiltration waters and surface leakage [7, 10, 11].

Rapid scientific advances in soil–plant interactions from recent years have generated a ripple effect for trends on fertilizers market [21]. As a consequence, farmers today are presented with a variety of options that promise success for their crops. From mineral to organic components, besides various formulations that stimulate soil biota or plant performance, the list of options is expanding [28].

The evaluation of the need for NPK fertilizers (minerals and organic) is carried out on the basis of the calculation of the optimal economic doses (DOE), the method being formalized in Romania and currently used in the studies executed for different beneficiaries by the County Soil and Climate and Agrochemical Studies Offices [19, 20].

Food security depends on agriculture, and agricultural security depends on water security and fertilizer security [27].

## MATERIALS AND METHODS

The necessary activities in carrying out this study consisted in a broad information and documentation from literature, in soil analyses, in the preparation of the germination bed, in sowing, in applying chemical and organic fertilizers, in performing phytosanitary treatments when appropriate, in harvesting, in data interpretation, and in the development of fertilization plans [23].The research was carried out both on the Curtici farm, as well as in the research laboratories of the soil science department of the Life Sciences University in Timisoara, where a series of analyses and interpretations were carried out [16].

The following types of soils were identified on the ground: chernozem, preluvosol and alluviosol and, following the laboratory analyses, it has been established that their natural fertility is good and very good. [17]

The methods used consisted in a series of calculations and interpretations regarding the necessary NPK fertilizers. It was necessary to have good knowledge of the cultivated surface, the practiced crop rotation, the soil type and the main features of the soils, the estimation of the planned crops, the climatic conditions, the specific nutrient consumption for each crop, as well as the moments of application of the organic and mineral fertilizers [18], [22], [24].

## RESULTS AND DISCUSSIONS

Research was carried out within an agricultural holding that works 600 ha of land and is based on the territory of Curtici in Arad County.

The fertilization plan for basic crops refers to wheat, barley, maize, and rapeseed. Grain maize is the most extensive crop on the farm, occupying 400 out of the 600 ha. The crop

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rotation takes 3 years, from maize and wheat to rapeseed.

The identified soils were chernozem, preluvosol and alluviosol and their different subtypes. Following the laboratory analyses, it was established that the physical, chemical, and hydro-physical properties of these soils allow the cultivation, in good conditions, of wheat, barley, maize and rapeseed, along with the climate conditions specific to the area.

The state of soil fertility in the researched area provides favourable conditions for the growth and development of wheat, maize, barley and rapeseed.

The cultivated cultivars and hybrids are presented in Table 1.

Table 1. The main crop cultivars/hybrids cultivated

| Crop | Cultivar/Hybrid |
|---|---|
| Barley | Dana (Fundulea) |
| Wheat | Glossa, Miranda (Fundulea) |
| Maize | DKC 5070, DKC 4943 |
| Rapeseed | Traviata (KWS), Arsenal (Limagrain) |

Source: Own determination.

The holding has several parcels cultivated with cereals, as shown in Table 2.

The highest amount of nutrient necessary in wheat is nitrogen because it is the element consumed in the highest proportion.

Table 2. The necessary nutrients for the wheat crop

| Topo plot | Total necessary nutrients | | | | | |
|---|---|---|---|---|---|---|
| | N | | $P_2O_5$ | | $K_2O$ | |
| | kg/ha | t | kg/ha | t | kg/ha | t |
| A 262 | 160 | 7.80 | 60 | 3.10 | 80 | 4.10 |
| A 347 | 160 | 4.30 | 60 | 1.60 | 80 | 2.10 |
| A 320 | 160 | 10.70 | 100 | 6.70 | 80 | 5.40 |
| A 351 | 160 | 5.50 | 60 | 2.20 | 80 | 2.90 |
| A 352 | 160 | 23.00 | 70 | 10.00 | 80 | 11.50 |
| A 216 | 160 | 7.50 | 120 | 5.70 | 80 | 3.80 |
| TOTAL | | 58.80 | - | 29.30 | - | 29.80 |

Source: Own calculation.

In wheat, nitrogen is the nutritional element that enters the formation of production components, having a favourable influence on rooting and twinning of plants. At the same time, it increases the number and mass of the grains in the spike and improves their content in proteins. The largest accumulation of nitrogen occurs in the straw and ear phases, while in the milk phase, the consumption of nitrogen decreases. Tables 3 and 4 present the necessary nutrients as mineral fertilizers in the analysed plots.

Table 3. Mineral fertilization plan in wheat

| Topo plot | Total necessary nutrients | | | | | |
|---|---|---|---|---|---|---|
| | N | | $P_2O_5$ | | $K_2O$ | |
| | kg/ha | t | kg/ha | t | kg/ha | t |
| A 262 | 22 | 1.10 | 43 | 2.20 | 16 | 0.80 |
| A 347 | 32 | 0.80 | 43 | 1.10 | 16 | 0.40 |
| A 320 | 32 | 2.10 | 83 | 5.60 | 16 | 1.10 |
| A 351 | 32 | 1.20 | 43 | 1.50 | 16 | 0.60 |
| A 352 | 32 | 4.60 | 53 | 7.60 | 16 | 2.30 |
| A 216 | 32 | 1.50 | 103 | 4.90 | 16 | 0.80 |
| TOTAL | | 11.30 | - | 22.90 | - | 6.00 |

Source: Own calculation.

In case of wheat, it is recommended that fertilizers with phosphorus and potassium to be applied under the ploughed soil, and the complex fertilizers, when preparing the germination bed. Nitrogen fertilizers will be applied fractionally: 50% before sowing and the other half in winter, when the soil is frozen, or in the spring, by mid-March.

Phase fertilization (with foliar fertilizers with macro- and micro-elements), associated with the chemical control of weeds or diseases and pests, results in effective increases in wheat production.

In maize, both complex fertilizers based on NPK (20:20:0) and foliar fertilisers were applied. The complex ones were incorporated in the spring, with the seed by a single passage, while foliar ones, in vegetation when the maize had 6 and 8, respectively, leaves, together with the Adengo herbicide.

Following the fertilization plans established for the 600 ha that the holding cultivates with wheat, maize, barley, and rapeseed, the productions were clearly superior (Table 5 and Figure 1).

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Table 4. Fertilization of the main crops during the period 2020-2021

| Crop | Type of fertiliser 2020-2021 | Dosage (kg) 2020-2021 | Type of fertiliser 2020-2021 | Dosage (kg) 2020-2021 |
|---|---|---|---|---|
| Wheat | NPK 20:20:0 (Fall) | 200 | NPK 20:20:0 (Fall) | 220 |
| | Urea (Spring) | 150 | Urea (Spring) | 150 |
| | Nitrocalcar (Spring) | 100 | Nitrocalcar (Spring) | 100 |
| | t1 + foliar 25 March foliar fungicide insecticide r microfertiliser | 10 l/ha | t1 + foliar 25 March foliar fungicide insecticide r microfertiliser | 10 l/ha |
| | t2 + azospeed 25 May fungicide insecticide azospeed | 10 l/ha | t2 + azospeed 25 May fungicide insecticide azospeed | 10 l/ha |
| Maize | NPK 20:20:0, Spring *Simultaneously with sowing – applied per row* | 250 | 270 | - |
| | Foliar Wuxal Zinc, *when the maize has 6 leaves, together with herbcide Adengo* | 2 | 2 | - |
| | Azospeed amino, *when the maize has 8 leaves, together with Nicosulphuron and Mezotrione* | 8 | 8 | - |
| Rape | NPK 20:20:0 (Fall) | 250 | NPK 20:20:0 (Fall) | 200 |
| | Sulphur + Boron (Fall) sulphur boron insecticide in Fall 4-6 leaves + regulator | 10 l (5 sulphur, 5 boron) | Sulphur + Boron (Fall) | 1-0 |
| | Nitrate 1 + foliar (Spring) 15-20 March | 150 | Nitrate 1+ foliar (Spring) | 150 |
| | t1 + foliar (sulphur boron azospeed before blooming) | 15 l (3 sulphur, 2boron 10 azospeed) | t1+ foliar (sulphur boron azospeed before blooming) | 15 l (3 sulphur, 2 boron 10 azospeed) |
| | Foliar - azospeed after blooming | 10 l/ha | Foliar - azospeed after blooming | 10l/ha |
| Barley | NPK 20:20:0 (Fall) | 200 | NPK 20:20:0 (Fall) | 250 |
| | Ammonia nitrate – At the end of winter 15-20 March | 150 | Urea (Spring) | 100 |
| | t1 + foliar - 25 March fungicide insecticide foliar | 10 l/ha | t1 + foliar - 25 March fungicide insecticide foliar | 10 l/ha |

Source: Own calculation.

Table 5. The average productions in the main crops in 2020 and 2021

| Crop | Mean production (kg/ha) | | Mean production (kg/ha) |
|---|---|---|---|
| | 2020 | 2021 | |
| Barley | 7,500 | 8,000 | 7,750 |
| Wheat | 8,000 | 8,200 | 8,100 |
| Maize | 8,100 | 8,200 | 8,150 |
| Rapeseed | 3,500 | 3,600 | 3,550 |

Source: Own calculation.

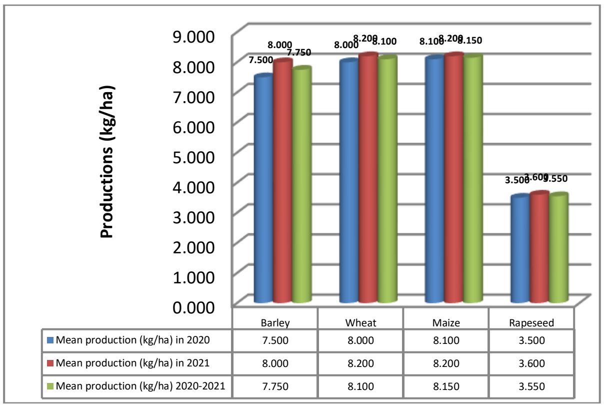


Fig. 1. Productions in the main crops in 2020 and 2021
Source: Own calculation.

## CONCLUSIONS

The main activity of the farm is the culture of cereals. The holding was founded in 2002 and, at first, 273 ha were cultivated, and a series of mechanization services were provided to different (physical and legal) people in the area, after which it expanded its area, so that it is currently working 600 ha.

The holding has several land plots, located both in the town of Curtici and in the neighbouring communes, of which in the present study we referred to 6 plots, respectively 262, A 347, 320, A 351, A 352, and 216.

The need for nutrients was 57.08 t/ha nitrogen, 78.33 t/ha of phosphorus, and 29.80 t/ha, potassium. In wheat, the largest quantity in nutrients is nitrogen, which has an essential role in the growth phase, after which it decreases.

The fertilizers with phosphorus and potassium are applied in the fall during ploughing, the complex ones, during the preparation of the germination bed, and nitrogen ones, at the beginning of spring.

In grain maize, the fertilizers used were micro-granulated ones containing NPK (20:

20:0), Foliar Wuxal Zinc, and Azospeed Amino. These were applied differently, namely: complex fertilizers, 250 and 270 kg/ha, respectively, in spring while sowing, applied per rows; Wuxal zinc foliar, 2 l/ha, when maize had 6 leaves, along with the Adengo herbicide; Azospeed amino, 8 l/ha when maize had 8 leaves, along with Nicosulphuron and Mezotrione.

In rapeseed, in addition to complex fertilisers and nitrogen-base ones, there was also sulphur and boron in the fall, along with a foliar fertiliser, in spring, and after blooming, Azospeed, in both years of research.

The productions were different from one year to another, according to the climatic conditions and the doses of fertilizers applied, as follows:

-In wheat, 7.5 t/ha in 2020 and 8.0 t/ha in 2021, respectively.

-In grain maize, between 8.0 t/ha in 2020 and 8.2 t/ha in 2021, respectively, with an average of 8.1 t/ha.

-In barley, between 8.1 t/ha in 2020 and 8.1 t/ha in 2021, respectively.

-In rapeseed, between 3.5 t/ha in 2020 and 3.6 t/ha in 2021, respectively.

It was thus found that the application of fertilizers increases production in all crops.

In conclusion, the correct establishment of fertilization plans is the most useful tool in establishing the recommended fertilizers, taking into account both the natural fertility of the soils on the farm, of their plants, of their nutritional needs, of the expected productions and of the expenses necessary to purchase the fertilizers. Thus, making early economic decisions related to what we need to cultivate, on what surfaces, to the works involve in each crop, to the quantities of necessary fertilizers and treatments helps purchase the necessary products in due time and at better prices. This is how one saves considerable price differences, resulting in lower production costs and higher profits.

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# WASTE MANAGEMENT - STUDY CASES

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***Abstract***

*Waste are a big problem in the economci and not only affecting environment quality. For this reason, it is compulsory to find solutions to reconvert these waste to avoid pollution. This paper presents the management and utilization of waste from the 11 wood industry factories in the city of Reghin, Mureș county, Romania and also a few case studies in agriculture where solutions were found to increase production and maintain environment quality. Wood waste is a category that can be used to obtain energy by burning or composting sawdust that can be used as fuel, sawdust that can be used for wood boilers, for pal panels or for paper pulp, or in animal husbandry as litter for animals. The purpose of the study was the study of waste management within these companies, where we found that a simple production results in several categories of waste such as: glass, plastic, paper, chemicals, oils, glues, paints, combustion ash, slag and the largest amount of wood waste. To increase production and reduce manufacturing costs, we recommend reintroducing this wood waste back into the production cycle, harnessing it in the form of thermal energy.*

***Key words***: *wood waste, energy recovery, case studies, Romania, France, Spain*

## INTRODUCTION

Wastes are a big problems related to environment pollution and human health. An important amount of waste materials could be reintroduced and recycled into the economic circuit by manufacturing processes [12].
By recycling industrial waste we could obtain a cleaner production and prevent environment pollution. In this way sustainable development could be achieved [17].
The EC Green Plan set up in 2020 has initiated a new approach of waste management for ensuring a sustainable development, more precisely, passing from linear to circular economy which means waste collection and recycling and its reuse as input raw materials in the production process [5].
There are many types of wastes from industry, agriculture, forestry, tourism, constructions, households etc.
In Romania, wood waste represents a significant part of the total waste, because it results from numerous sources such as: industry, the development of green spaces, people's households, forest exploitation, construction and demolition [8]. As per the legislation, wood waste and its management is vaguely explained and no proper record is kept of it, according to existing reports. Wood waste falls into the category of non-hazardous industrial waste, where it requires a more detailed record [1, 2]. Even if every company is obliged to keep track of them by the authorities, this information is not taken over by the state institutions. In the European Union, wood waste management is much more efficient, as it is in the territory of Sweden or the United Kingdom, where the legislation is well regulated [11, 13].
According to Decision no. 2293 of December 2004, [3] wood waste was divided into three categories, but it is much better classified according to HG 856/2002.
The wood resulting from the categories mentioned in the law and not only, must be sorted and transported to the storage and utilization units. The sorting is done according to the process from which the waste results, because it may also contain other residues that require a different treatment such as: metals, paints, heavy metals, glues, plastics, varnishes [4].
Wood waste must be stored in spaces designed for this purpose, such as sheds or concrete sheds, avoiding storage on the ground. They must be supervised, because it can be a factor of pollution through the

processes of putrefaction or fermentation, production of leachate, can harbor pests and is an easily flammable material. For these reasons, and because it is easy to recover, on a European level, landfill storage is restricted [6, 7, 15]. In Romania, the main form of valorization of wood waste is burning or using it as a raw material in the production of wood. It is less used for obtaining coals, in animal husbandry, obtaining compost, biogas or for smoking coffee and fish [10].

The wood waste resulting from the production process is usually burned in the company's thermal power plants to obtain thermal energy, raw material for the pile and its transformation into briquettes and pellets (they have a higher calorific value than raw wood).

Wood waste can have many destinations and can be used without affecting the environment through their degradation [8, 9, 14]. At the present time in our country, unfortunately, the chain of wood waste recovery cannot be optimized. Recent data shows that everywhere in Europe, improper storage of this waste and illegal burning generate pollutants such as dioxin. Among the economic agents in the city of Reghin, wood waste represents 29% of the non-hazardous waste generated by industrial and commercial companies with more than 10 employees. Of these, 61% are used as raw material in the paper and construction panel industry, 28% are used as fuel in the form of briquettes or pellets, and 11% are stored at landfills or destroyed improperly. The resulting waste that does not belong to the hazardous waste class (treatment with creosote or varnishes containing heavy metals) can be recycled [16, 24].

## MATERIALS AND METHODS

This paper selected a few case studies of waste management which were solved using specific solutions.

A part of them regard the management of waste resulting from forest industry (wood waste management).

In this respect, it is given the example of 11 companies whose activity is wood processing, where the waste is sorted and collected in the production sections where it comes from. Paper and cardboard packaging is collected in boxes designed for this purpose. Mixed municipal waste is collected in bins at the workplace, and the bins are emptied into 4 cubic meter metal containers, which are then collected by the local sanitation company.

Sawdust is collected and transported to the storage from the thermal plant through the exhaust system. Sawdust, board scraps and veneer are collected at the generation site in wooden crates and then manually transported and dumped into the waste trailer located next to the section, the trailer being then transported by the ifron to the wood waste dump at the thermal plant. Ash residues from combustion and slags from incineration are collected in metal containers of 4 cubic meters, they can be transported with the garbage truck. They are transported to the transfer station and sorting hall in Reghin.

The other types of waste are collected in metal containers of 200 liters, they being made up of paint and varnish waste containing organic solvents or other dangerous substances and absorbents, filter materials (including oil filters without any other specification), polishing materials, protective clothing contaminated with other hazardous substances, hydraulic oils and other engine, transmission and lubricating oils. They are taken over by a specialized company, S.C. Ro Ecologic Recycling S.R.L. located in Vidrasău (Ungheni city, Mureș County).

Domestic water and sludge from adhesives and glues reach the Reghin sewage treatment plant (Reghin Municipality/Mureș County).

Another part of waste management regards agriculture offering examples of solutions found to increase production, animal health and wellness, and protect environment.

## RESULTS AND DISCUSSIONS

***Waste management- Case studies from wood industry- recovery in thermal energy***

Following the study of the 11 economic companies dealing with wood processing in the city of Reghin (Fig. 1), we obtained the following results: in the technological flow, after the wood enters the factory, it goes through a complex technological process, from each stage from raw material to finished product, waste results. Much of the waste results from timber processing activities: drying, sawing, splitting, sawing, planing, calibrating, profiling, milling, drilling and grinding, generating: sawdust (Photos 3 and 4), dust, wood chips, sawdust, board and veneer scraps.

As a result of wood processing, a larger amount of wood waste results than the amount of wood in the finished product.

From these activities remains, on the one hand, waste, on the other, wood dust (from very softwood, hardwood and composites) that can cause serious ailments, especially to the respiratory system.

Finishing, gluing and painting activities follow.

Through the activity of gluing solid panels and furnishing of pal panels, it generates sludges of adhesives and glues.

When finishing, surfaces that are not uniform are grouted and sanded resulting in mineral or chemical waste depending on what the grout contains.


Fig. 1. Economic agents carrying out activities in the wood industry in the city of Reghin, Mureş county Source: google.com.

Various oils result from the use of many machines and machines.

The activity of painting with varnishes and paints generates waste of paints and varnishes with a content of organic solvents and absorbents, filter materials (including oil filters, without other specification), polishing materials, protective clothing, contaminated with dangerous substances.

These wastes contain chemical agents very dangerous for humans such as: methanol, toluene and xylene in the case of solvents or formaldehyde and isocyanates.

Table 1. The quantities of waste generated in 2021 according to HG 856_2002.

| Waste type | Measurement unit | Quantity |
|---|---|---|
| 20 03 01 Mixed municipal waste | Ton | 25,680 |
| 03 01 05 Sawdust, shavings, shavings, scrap wood and veneer, other than those specified in 03 01 04 | Ton | 638 |
| 08 04 12 slurries of adhesives and glues other than those specified in 08 04 11 | Ton | 2.4 |
| 20 01 02 glass | Ton | 0.052 |
| 15 01 01 paper and cardboard packaging | Ton | 1.34 |
| 19 01 12 fly ash and slag, other than those mentioned in 19 01 11 | Ton | 11.1 |
| 08 01 11 waste paints and varnishes containing organic solvents or other dangerous substances | Ton | 4.15 |
| 15 02 02 absorbents, filter materials (including oil filters not otherwise specified), polishing materials, protective clothing contaminated with hazardous substances | Ton | 0.137 |
| 13 02 08 other engine oils, lubrication transmission | Ton | 0.005 |
| 13 01 13 other hydraulic oils | Ton | 0.015 |
| **Total** | Ton | 682.879 |

Source: S.C. Amis Mob S.A.

**The place and thew conditions of waste storage within the analyzed companies.**

Mixed municipal waste is stored (Photo 6) in metal containers of 4 cubic meters that can be transported with the garbage truck, the containers are placed in a box surrounded by a fence and has a concrete platform (Photo 1, 2 and 5).

Adhesive and glue sludges are collected in an underground concrete basin.

Glass waste is stored in 200 liter metal drums located inside the finished product warehouse.

Paper and cardboard packaging is stored in a special box intended for this purpose, located inside the warehouse of finished products.

Combustion ash and slag are stored in metal containers of 4 cubic meters that can be transported with the garbage truck, on the concrete platform next to the thermal power plant.

Used oils are stored in metal drums of 200 liters in the oil store.

Photo 1. Storage shed, outside the building
Source: Original S.C. AmisMob

Photo 2. Building with central, exterior
Source: Original S.C. AmisMob.

Waste paints and varnishes containing organic solvents and absorbents, filter materials (including oil filters without other specification), polishing materials, protective clothing contaminated with hazardous substances are stored in 200-liter metal barrels in the hazardous waste warehouse.

Photo 3. Sawdust storage inside the shed
Source: Original S.C. AmisMob.

Photo 4. Sawdust storage, inside the shed
Source: Original S.C. AmisMob.

Photo 5. Storage of wooden waste of various sizes, inside the shed
Source: Original S.C. AmisMob.

The wood waste (sawdust, shavings, shavings, board and veneer scraps) is stored in the shed next to the own thermal plant (Photo 7). The shed is a construction with metal poles, a tin

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roof, surrounded by masonry and with a concrete floor.

Photo 6. Storage of large wooden waste, outside
Source: Original S.C. AmisMob.

Methods of energy recovery of waste: wood at commercial companies in the city of Reghin: Wood waste (sawdust, shavings, shavings, scraps of boards and veneer) is used by burning in the boilers of the thermal plant, in order to produce the thermal energy needed to heat the production spaces and dry the timber in the drying facilities (Photo 8). These drying facilities are rooms made entirely of non-oxidizing metals and insulating material (mineral wool), the timber is dried through a ventilation system and pipes that carry out the heat transfer. The whole process is coordinated with the help of software.
Large-sized wood waste goes through a shredding and chopping process (Photo 9).
The other types of waste are taken over by authorized companies.

Photo 7**.** Central heating
Source: Original S.C. AmisMob.

Photo 8**.** Lumber drying plant
Source: Original S.C. AmisMob.

Photo 9. Equipment for shredding large-sized wood waste
Source: Original S.C. AmisMob.

**Case study:** Wood waste management within the company S.C. *OlteanProdlemn* S.R.L.
Through this study, we aimed to highlight the management and utilization of waste from the factory of wood products (beams, boards, brewery sets, pellets, etc.) S.C. *OlteanProdlemn* S.R.L. As a result of production, a series of waste categories result, which for the most part, quantitatively speaking, is represented by wood waste, followed by household waste, rubber, metals, used oils, glues, paints, chemicals, ash combustion and slag. In order to reduce costs and increase production, wood waste is reintroduced into the technological cycle and utilized in the form of thermal energy, but also processed into pallets and briquettes, which are then sold.
The production activities that generate waste are, just like those of the S.C. Amis Mob S.A. factory, namely: drying, transport, cutting, splitting, cutting, planing, calibrating, profiling, milling, drilling, grinding, but also

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the other operations are waste generators such as: varnishing, painting, gluing, etc.

**Case study:** Methods of collection and storage of wood waste within the company R.A.G.C.L. Reghin S.A.

The waste is sorted and collected in the production sections, from where it is then transported to the storage site according to its type and use. These wastes are represented by metals, glass, paper, cardboard, plastic, tires, household waste, etc.. They are then taken over by R.A.G.C.L. Reghin S.A.

The sawdust and dust is collected and transported to the storage site by means of the exhaust plant. Larger wood scraps (board scraps, veneer, sawdust, shavings, etc.) are collected in containers, then transported by forklift trucks to the place of storage.

The storage place is represented by a shed near the thermal plants and the pellet production hall.

Combustion ash and slag are stored in transportable metal containers.

They are picked up and transported by an authorized company.

The other types of waste are collected in barrels and metal containers, these being represented by glues, organic solvents, paints, varnishes, oils, and other hazardous waste. They are sent to a warehouse specially designed for hazardous waste.

Table 2. The quantities of waste generated, recovered and stored in 2021, wood waste by month

| | Month | Waste quantity (t) | | |
|---|---|---|---|---|
| | | Generated | Recovered | Remaining in stock |
| 1 | January | 419 | 234 | 185 |
| 2 | February | 373 | 278 | 95 |
| 3 | March | 495 | 423 | 72 |
| 4 | April | 223 | 148 | 75 |
| 5 | May | 75 | 0 | 75 |
| 6 | June | 305 | 230 | 75 |
| 7 | July | 365 | 317 | 47 |
| 8 | August | 348 | 302 | 46 |
| 9 | September | 315 | 267 | 47 |
| 10 | October | 340 | 276 | 64 |
| 11 | November | 375 | 284 | 91 |
| 12 | December | 347 | 299 | 48 |
| | **TOTAL** | **3.980** | **3.058** | **920** |

Source: S.C. *OlteanProdlemn* S.R.L.

They are taken over by an authorized company called: S.C Nida Eco S.R.L. The quantities of waste collected by category are presented in Tables 2-8.

Table 3. Amounts of sawdust generated in the year 2021 (t)

| | Month | Waste quantity (t) | | |
|---|---|---|---|---|
| | | Generated | Recovered | Remaining in stock |
| 1 | January | 150 | 108 | 42 |
| 2 | February | 120 | 120 | 0 |
| 3 | March | 189 | 189 | 0 |
| 4 | April | 75 | 75 | 0 |
| 5 | May | 0 | 0 | 0 |
| 6 | June | 113 | 113 | 0 |
| 7 | Iulie | 170 | 170 | 0 |
| 8 | August | 105 | 105 | 0 |
| 9 | September | 155 | 155 | 0 |
| 10 | October | 125 | 125 | 0 |
| 11 | November | 166 | 166 | 0 |
| 12 | December | 121 | 121 | 0 |
| | **TOTAL** | **148** | **1.447** | **42** |

Source: S.C. *OlteanProdlemn* S.R.L.

Table 4. Amounts of metal generated in the year 2021 (t)

| | Month | Waste amount (t) | | |
|---|---|---|---|---|
| | | Generated | Recovered | Remaining in stock |
| 1 | January | 0 | 0 | 0 |
| 2 | February | 0 | 0 | 0 |
| 3 | March | 0 | 0 | 0 |
| 4 | April | 0 | 0 | 0 |
| 5 | May | 0 | 0 | 0 |
| 6 | June | 0 | 0 | 0 |
| 7 | Iulie | 0 | 0 | 0 |
| 8 | August | 0 | 0 | 0 |
| 9 | September | 0 | 0 | 0 |
| 10 | October | 0 | 0 | 0 |
| 11 | November | 2.75 | 0 | 2.75 |
| 12 | December | 0 | 0 | 0 |
| | **TOTAL** | **2.75** | **0** | **2.75** |

Source: S.C. *OlteanProdlemn* S.R.L.

Table 5. The quantities of household waste generated in 2021 (t)

| | Month | Waste quantity (Kg) | |
|---|---|---|---|
| | | Generated | Eliminated |
| 1 | January | 150 | 150 |
| 2 | February | 112 | 112 |
| 3 | March | 145 | 145 |
| 4 | April | 116 | 116 |
| 5 | May | 125 | 125 |
| 6 | June | 110 | 110 |
| 7 | July | 95 | 95 |
| 8 | August | 86 | 86 |
| 9 | September | 123 | 123 |
| 10 | October | 133 | 133 |
| 11 | November | 106 | 106 |
| 12 | December | 111 | 111 |
| | **TOTAL** | **1.412** | **1.412** |

Source: S.C. *OlteanProdlemn* S.R.L.

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Table 6. The quantities of tires generated in the year 2021 (bucati)

| | Month | Waste quantity (per piece) | |
|---|---|---|---|
| | | Generated | Remaining in stock |
| 1 | January | 0 | 0 |
| 2 | February | 0 | 0 |
| 3 | March | 0 | 0 |
| 4 | April | 0 | 0 |
| 5 | May | 0 | 0 |
| 6 | June | 0 | 0 |
| 7 | July | 0 | 0 |
| 8 | August | 2 | 2 |
| 9 | September | 0 | 0 |
| 10 | October | 0 | 0 |
| 11 | November | 3 | 3 |
| 12 | December | 0 | 0 |
| | **TOTAL** | **5** | **5** |

Source: S.C. *OlteanProdlemn* S.R.L.

Table 7. The amounts of ash and slag generated in the year 2021 (t)

| | Month | Waste quantity (t) | |
|---|---|---|---|
| | | Generated | Eliminated |
| 1 | January | 0.15 | 0.15 |
| 2 | February | 0.17 | 0.17 |
| 3 | March | 0.12 | 0.12 |
| 4 | April | 0.18 | 0.18 |
| 5 | May | 0.16 | 0.16 |
| 6 | June | 0.15 | 0.15 |
| 7 | July | 0.14 | 0.14 |
| 8 | August | 0.13 | 0.13 |
| 9 | September | 0.11 | 0.11 |
| 10 | October | 0.20 | 0.20 |
| 11 | November | 0.18 | 0.18 |
| 12 | December | 0.19 | 0.19 |
| | **TOTAL** | **0.188** | **0.188** |

Source: S.C. *OlteanProdlemn* S.R.L.

Table 8. Amounts of used oils generated in the year 2021 (Kg)

| | Month | Waste quantity | |
|---|---|---|---|
| | | Generated | Eliminated |
| 1 | January | 35 | 35 |
| 2 | February | 40 | 40 |
| 3 | March | 66 | 66 |
| 4 | April | 70 | 70 |
| 5 | May | 50 | 50 |
| 6 | June | 0 | 0 |
| 7 | July | 110 | 110 |
| 8 | August | 44 | 44 |
| 9 | September | 81 | 81 |
| 10 | October | 91 | 41 |
| 11 | November | 60 | 60 |
| 12 | December | 44 | 44 |
| | **TOTAL** | **651** | **651** |

Source: S.C. *OlteanProdlemn* S.R.L.

***Waste management-Case studies from agriculture***

A large part of waste represents biodegradable wastes consisting or organic matter of vegetal and animal origin.

It is about:
- vegetal biomass including various crops, straw, roots, tress leaves, seeds, energetic crops like rape, maize, sunflower;
-animal waste, including solid manure and purine;
-industrial waste: food waste, waste resulting from beer, sugar, wine, milk, alchool, milling industry;
-forest waste;
-commercial waste: textiles, paper etc.
-household waste etc.

A high attention is paid to solutions which are included in regenerative agriculture which maintains environment qualities (soil, water, air).

A few examples of case studies in waste management in agriculture are presented below.

(a) To maintain soil quality and biodiversity, a high production level and a low production cost, the Spanish farmers growing strawberries started to implement organic agricultural practices replacing the plastic waste with biodegradabil paper and pest control was ensure by bioplants [18].

(b)In dairy farming, the use of a supplement of fat in cows diet, has led to a higher milk yield andfat, and to a benefic effect on cows health and reproduction [19].

(c)In Spain, the efficiency of land use was increased by improving the nutrients offered to crops, reducing greenhouse gas emissions and increasing dairy cows yield. For this purpose, manure was combined with mineral fertilization bazed on Selenium and Sulphurus, resulting a higher grass production, a better feeding for cows and a highr milk production per ha. More than this, gas emmissions were reduced by Carbon incorporation into the soil [20].

(d)Rotation grazing was optimized by establishing a plan of grassland use by rotation and improving the floral composition with additional species during summer season. In this way, the length of grazing was longer and costs were reduced, but milk production declined [21].

(e)In France, using special enzymes in dairy cows diet to stimulate the digestion of the food rich in starch and fibres, it was increased milk yield and fat, milk quality and animal health and fertility [22].

(f)In Spain, Fruites Caberol produces and sells a large variety of fruits (cherries, apricots, nectarines, peaches, pears and apples) which are achieved by respecting the global norms regarding sustainable agriculture oriented to a high product quality and also preserving the quality of the environmental factors [23].

## CONCLUSIONS

Wood waste (sawdust, shavings, shavings, scraps of boards and veneer) can be used as energy by burning in the boilers of the thermal plant in order to produce the thermal energy needed to heat the production spaces and dry the timber in the drying facilities. Drying facilities are rooms made entirely of non-oxidizing metals and insulating material (mineral wool and other insulating materials), where the timber is dried through a ventilation system and pipes that carry out the heat transfer. Large wood waste can be chopped for use in power plants.

The waste intended for the production of pellets and briquettes is chopped, shredded and pressed with the necessary equipment. As well as their packaging machines for the purpose of preparation for marketing.

The utilization of wood waste has a positive impact on the environment because:

-they are easy to store;

-the burning process is clean compared to some petroleum fuels (results in less harmful emissions);

-comes from a renewable resource;

-more economical than fuels and gas;

-reducing air, water and soil pollution by reducing inappropriate storage areas;

-protecting water, air and soil through good management;

-ecological fuel can be produced from biomass, replacing petroleum ones.

But the capitalization also has disadvantages such as:

-requires large storage space;

-requires an expensive manufacturing process and labor;

-continuous supply of raw material.

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# ANALYSIS OF RURAL INCOME INEQUALITY IN NIGERIA: BEFORE AND DURING THE DEMOCRATIC ERA

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***Abstract***

*Income inequality is a global issue affecting all and sundry across the globe in both developed and developing economies. It could result in a high probability of revolution, high rent-seeking policies, a breakdown of social cohesion and a signal of low democracy. Democracy as a form of government was created to ensure that every citizen enjoys the dividends of government. If this is true, democracy should therefore serve to reduce income inequality in the world. The extent to which this is true for Nigeria is yet to get sufficient research interest. Therefore, this study examined the income inequalities in rural Nigeria before and during the democratic era and measured the contributions of different socio-economic factors to income inequality. This study utilized the General Household Survey Panel and the National Consumers Survey data. This study employed the Gini coefficient, theil index, Lorenz curve, and the regression-based inequality decomposition method as techniques of data analysis. The result revealed that income inequality had decreased by 6% from the pre-democratic era to the current democratic era. The proportion of middle-class population has increased by 1.35%. The years of education contributed the most to total inequality (23.5%), the dependency ratio contributed -15.3%, age contributed -0.59%, household size contributed 6.2%, gender of household head contributed 0.03%, and marital status contributed 0.1% to the total income inequality. There is thus a need to gear programmes and policies to boost the education system, empower women and strengthen democratic institutions to ensure income equality.*

***Key words*****:** *democracy, determinants, Gini coefficient, income inequality, rural Nigeria*

## INTRODUCTION

Income inequality is a global issue affecting all and sundry across the globe in both developed and developing economies. This makes it appear in the Sustainable Development Goals (SDG 10). The high rate of inequality globally, with its implications for macroeconomic stability and economic growth, is of great concern to academics and policymakers [1, 2]. Income inequality has a significant relationship with the incidence of poverty within a population. Omotola and Kabir [24] opined that the increasing rate of poverty and income inequality has been a major concern among economists and policy experts because they are the major factors hindering the development of any nation. Income inequality and poverty contributes to the halting of the globalization process [26].

Widening income inequality is a defining challenge that calls for urgent attention across the board as it has a significant effect on political and economic stability. Sub-Saharan African countries have recorded the highest income inequality level in recent years. The human development index (HDI) for Africa increased very marginally from 0.366 in 1980 to 0.561 in 2020, which has, however, been the worst since 1980 as compared to other regions [24, 30, 31]. Nigeria was categorized as a low human development country due to its low lifespan, education level, and gross national income per capita [14]. Evidence abounds that shows that income inequalities and poverty are at a high rate, especially in the rural areas where the majority are engaged in farming. In Nigeria, income inequality has been on the rise since as far back as the early 1980s, during the second republic. The trend was on a sharp rise between 1977 and 1985 and reached a peak index of 0.7391 in 1999 and 2004 [6, 22, 23]. The country also recorded a Gini index of 58.3% and 69% in 2005 and 2010, respectively [32]. In addition, Nigeria was ranked 161st in the world with an HDI of 0.539 in 2020 [31].

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Nigeria is regarded as Africa's largest economy, but more than 40% of the population lives in poverty, while a few high-income earners control a larger proportion of the wealth and are constantly increasing wealth [19, 21]. This shows a high level of income inequality in the country. A high level of income inequality could result in a low level of democracy, a high probability of revolution, and high rent-seeking policies [28]. Income inequality, which can break down social cohesion and cause an economy to fall into a vicious cycle, can also endanger democratic institutions [28]. Democracy as a form of government was created to ensure that every citizen enjoys the dividends of government. The dividend of democracy is expected to trickle down to every individual in the nation. If this is true, democracy should, therefore, serve to reduce income inequality in the country. The extent to which this is true for Nigeria is yet to get sufficient research interest as previous studies on Nigeria's income inequality did not show if democracy had reduced the level of income inequality in the country [5, 29].

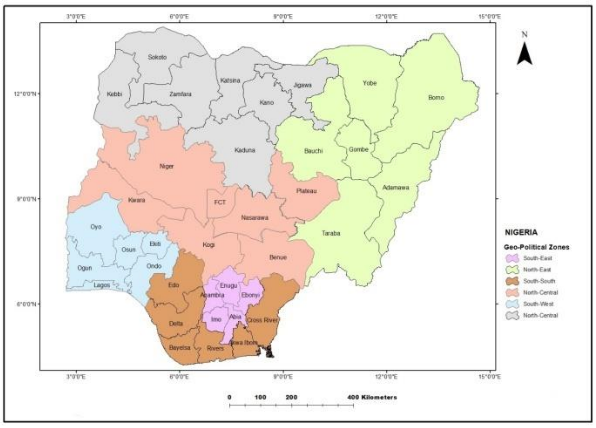
The present study, therefore, analysed the income inequality across regions in rural Nigeria before and during the fourth republic (democratic era) by providing insight into whether subsequent governments in the fourth republic have been implementing the right policies to stem the tide of income inequality. Specifically, the study: profiled the socioeconomic features of rural households in Nigeria; measured the income inequality and income shares in rural Nigeria before and during the democratic era; and decomposed the income inequality to measure the contribution of different socio-economic factors to income inequality.

Identifying factors responsible for income inequality is of great importance to addressing the issue of income inequality by tailoring policies and programmes towards them.

Thus, this research will be of great importance to governments and policymakers to reduce income inequality in the short run and eradicate it in the long run.

## MATERIALS AND METHODS

The study area is Nigeria (Map 1). Nigeria is the most populous country and largest economy in Africa. The major livelihood of the larger population is agriculture and allied activities, especially among rural households [9, 15].




Map 1. Map of Nigeria showing the six geological zones
Source: EnvironReview [11].

This study used data from the recent General Household Survey (GHS) Panel, and the National Consumers Survey (NCS) contained in the Poverty Profile of Nigeria (1985–1996), both gotten from the Nigeria Bureau of Statistics (NBS). The GHS was used to represent the democratic era, while the NCS of 1996 was used because it was the last National Consumer Survey before the transition to the 4th republic (democratic era). The data usedin this study covered 3,112 rural households across the six geopolitical zones of Nigeria.

18.22% of the households surveyed were from the North-Central, 17.29% from the North-East, 23.17% from the North-West, 17.99% from the South-East, 16.42% from the South-South and 6.91% from the South-West.

In this study, the Gini coefficient and theil index were employed to measure income inequality before and during democracy.

A regression-based inequality decomposition method was used to measure the contribution of socioeconomic factors to income inequality.

The Gini coefficient measures inequality based on the Lorenz curve. It is the ratio of the area between the equality line and the Lorenz curve, and the total area under the equality line.

It has values ranging from 0 to 1. 0 signifies absolute equality in income distribution while 1 signifies perfect income inequality. Values closer to 0 indicate more income equality distribution while values closer to 1 indicate higher income inequality distribution. The Gini coefficient is the most commonly used economic measure of inequality. It has been widely used by researchers in measuring income inequality [5, 12, 13, 27, 29]. It is expressed as:

$$G = 1 - \sum(\mathrm{Hh_i} + 1 - \mathrm{Hh_i})(\mathrm{Inc_i} - \mathrm{Inc_i} + 1) \quad \ldots\ldots (1)$$

where:

$\mathrm{Hh_i}$ is the cumulative percentage of households, $\mathrm{Inc_i}$ is the cumulative percentage of income and G is income Gini.

Following Usman et al. [32], the theil index was also used to measure income inequality. It is important for group decomposition by measuring the deviation from perfect income equality. It is represented as:

$$E(1) = \frac{1}{n}\sum_i \left(\frac{y_i}{y}\right) ln \left(\frac{y_i}{y}\right) \ldots\ldots (2)$$

where:

E(1) is the theil index, $y_i$ is the income of the individual, y is the mean income, $i$ is the average income, $\sum_i$ is the summation of income, $ln$ is the logarithm of the geometric mean of the ratio, and $n$ is population size.

The regression-based inequality decomposition was used to examine the factors contributing to income inequality following Akin-Olagunju and Omonona [5] and Usman et al. [32]. It is important in explaining the structure and distribution of income. It shows how much individuals/households or groups have a different impact on income inequality [32]. The coefficients obtained from the OLS regression (Equation 3) were used to find the percentage contribution of the variables to the level of inequality (Gini coefficient), also known as the factor inequality weights,Sj (Eq. 4).

The OLS used is explicitly specified as:

$$IN_i = \beta_0 + \beta_1 A + \beta_2 G + \beta_3 E + \beta_4 H + \beta_5 M + \beta_6 D + \varepsilon_i \quad \ldots\ldots (3)$$

where:

IN = Rural households' annual income (Naira)

A = Age of rural household heads (years),

G = Gender (dummy: male = 1, female = 0),

E = Education (years),

D = Dependency ratio (number of people depending on household head),

H = Household size (number),

M = Marital status (married = 1, otherwise = 0),

$\varepsilon_i$ = Error term.

The factor inequality weights, $S_j$, is expressed as:

$$S_j = \frac{Cov(\beta_j X_j, InY)}{\sigma(InY)} = \frac{\beta_j * \sigma(X_j) * cor(X_j, InY)}{\sigma(InY)} \ldots (4)$$

where:

$\beta_j$ represents the estimated coefficient from the OLS regression of the jth characteristic of an individual, $X_j$ represents the value taken on by the jth characteristic, $ln$Y is the natural logarithm of income, $\sigma(X_j)$and $\sigma(InY)$ are the standard deviations of $X_j$ and of $InY$, respectively, $cor(X_j, InY)$ is the correlation between factor j and $InY$. Therefore, $S_j(InY)$ indicates the share of jth characteristic in inequality (Gini index), because $X_j$ is unequally distributed among the households. A positive $S_j$ implies that j is an inequality-increasing factor whereas the negative $S_j$ means that factor j decreases income inequality.

## RESULTS AND DISCUSSIONS

### The percentage distribution of respondents by household head and marital status

Table 1 shows the percentage distribution of respondents by the household head and marital status. The majority of the households in rural Nigeria were headed by a male, with the highest regional occurrence found in the North West (95.01%) and the lowest in the South-South (71.62). While only 19.18% of rural Nigerian households are headed by a woman, the South East has the highest regional occurrence (36.61%) and the North West has the lowest (4.99%). This result corroborates the findings of Usman et al. [32] that most household heads in rural Nigeria were male. This implies that the males dominated the household heads in rural Nigeria, which might have made them have a say over their female counterparts in decision-making. The majority of the respondents were married (90.5% of the males and 78.9% of the females) and were mostly monogamists. This implies that the rural areas were dominated by married people. Thus, married people have dependants and have the task of providing for their household needs. About 13 per cent of the females were not married and 8 per cent of the males were not married (Table 1). This suggests that single females were more common than single males in rural Nigeria. This could be a result of the larger proportion of females in rural Nigeria. Similarly, widows (7.9%) were more than widowers (0.8%) among the rural population in Nigeria. This could be due to mental and physical stress imposed on the male as the head of the household, which disposed them to illness at an older age.

Table 1. Percentage distribution of respondents by household head and marital status

| Variables | Category | North Central | North East | North West | South East | South-South | South West | Total |
|---|---|---|---|---|---|---|---|---|
| Gender | Male | 81.13 | 91.08 | 95.01 | 63.39 | 71.62 | 73.95 | 80.82 |
| | Female | 18.7 | 8.92 | 4.99 | 36.61 | 28.38 | 26.05 | 19.18 |
| Married (Monogamy) | Male | 51.6 | 51.3 | 44.2 | 77.3 | 71.4 | 62.3 | 51.9 |
| | Female | 54.9 | 59.6 | 38 | 53.7 | 60.3 | 53 | 55.8 |
| Married (Polygamy) | Male | 39.9 | 39.3 | 45.4 | 18.3 | 23.8 | 29.4 | 38.6 |
| | Female | 26.5 | 16.7 | 42.7 | 26.7 | 24.4 | 29.9 | 23.1 |
| Never married | Male | 7.1 | 8.7 | 9.6 | 1.8 | 2.5 | 4.9 | 8 |
| | Female | 9.8 | 18.5 | 15.7 | 1.5 | 3.4 | 5.4 | 12.5 |
| Divorced | Male | 0.1 | 0.1 | 0.1 | 0.3 | 0.2 | 0.6 | 0.2 |
| | Female | 0.2 | 0.4 | 0.1 | 0.3 | 0.9 | 0 | 0.3 |
| Separated | Male | 0.3 | 0.3 | 0.2 | 0.7 | 1.1 | 1.2 | 0.5 |
| | Female | 0.6 | 0.1 | 0.1 | 0.7 | 1.1 | 1.9 | 0.5 |
| Widow | Male | 0.9 | 0.3 | 0.5 | 1.7 | 1 | 1.5 | 0.8 |
| | Female | 8.1 | 4.6 | 3.4 | 17.2 | 9.8 | 9.7 | 7.9 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

**Rural household size and percentage distribution of individuals by age group and gender**

Table 2 shows the distribution of average household size and individuals by age group and gender in rural households. The average household size in rural Nigeria was six people. Rural households love to have a larger household size, which serve as cheap farm labour and enhance farm output. This is because large household size contributes significantly to agricultural output in Nigeria. This corroborates Usman et al. [32], who found that the rural households in Nigeria had a larger household size of 6 people on average. The highest household size was recorded in the North East region (8 people), and the lowest was found in the South West (4 people). This could be a result of the practice of polygamous marriage, which was higher in the North East than in the Southwest. The highest dependency ratio was recorded in the North West (1.17), signifying a dependent population higher than the working population, while the lowest was recorded in the South-South region (0.68), which signifies that the working population was higher than the dependent population (Table 2). Rural Nigeria, in general, had a dependency ratio of 0.94, which shows a slightly higher proportion of the working population as against the dependent population.

The working population (age 15–64) represents 51.6% of the rural population, with 24.7% of the 51.6% being males, while the remaining 26.9% were females (Table 2). The dependent population (age 0–14 and 65+) represents 48.4% of the rural population. This suggests a relatively high level of the dependent population, which may reduce the per capita income in the households. Generally, in rural Nigeria, 7.7% of males and

7.2% of females were between 0 to 5 years of age; 6.3% of males and 6.1% of females were between the age group of 6 and 9 years; 7.9% of males and 6.9% of females of the rural population were between 10 and 14 years of age (Table 2). This suggests that a significant proportion (43.1%) of the entire rural population were children (less than 15 years old), while more than half of the population were adults. In total, 50.3% of the rural population were males, while 49.7% were females. Thus, males dominated the rural population in Nigeria.

Table 2. Household size and individual percentage distribution by age group and gender

| Age | Category | North Central | North East | North West | South East | South-South | South West | Rural Nigeria | Nigeria |
|---|---|---|---|---|---|---|---|---|---|
| | Average Household size | 5.7 | 7.9 | 7.4 | 4.3 | 4.9 | 4 | 5.9 | 5.5 |
| | Dependency ratio | 0.81 | 0.94 | 1.17 | 0.72 | 0.68 | 0.78 | 0.94 | 0.88 |
| 0-5 | Male | 6.1 | 8.4 | 9.9 | 5.5 | 5.6 | 5.8 | 7.7 | 7.3 |
| | Female | 5.8 | 7.1 | 9.4 | 5.1 | 5.1 | 6.3 | 7.2 | 6.9 |
| 6-9 | Male | 7.1 | 7.5 | 7.6 | 4.7 | 4.8 | 4.8 | 6.8 | 6.3 |
| | Female | 5.4 | 6.7 | 7.6 | 4.4 | 5.6 | 5.3 | 6.2 | 6.1 |
| 10-14 | Male | 8.4 | 8.5 | 9.4 | 6.2 | 6.9 | 6.6 | 8.3 | 7.9 |
| | Female | 7.4 | 7.6 | 6.9 | 5.3 | 7.1 | 6.5 | 6.9 | 6.9 |
| 15-64 | Male | 26.4 | 25.9 | 22.5 | 25.6 | 29.1 | 26.6 | 24.7 | 25.6 |
| | Female | 28.9 | 25.6 | 23.5 | 32.7 | 30.5 | 29.5 | 26.9 | 27.7 |
| 65+ | Male | 2.5 | 1.8 | 2.3 | 4.7 | 2.6 | 4.1 | 2.9 | 2.9 |
| | Female | 2 | 1 | 0.9 | 5.8 | 2.9 | 4.4 | 2.4 | 2.5 |
| Total | Male | 50.5 | 52 | 51.7 | 46.7 | 49 | 47.9 | 50.3 | 49.9 |
| | Female | 49.5 | 48 | 48.3 | 53.3 | 51 | 52.1 | 49.7 | 50.1 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

**Distribution of respondents by education and income**

Regarding educational status, the majority (77.80%) of the respondents had 11–16 years of education (Table 3). This implies that the majority had secondary school education, while only 22.20% can be said to have tertiary education. Education plays a vital role in raising rural income, meeting food needs, and addressing sustainable livelihoods [16]. The larger proportion (60.28%) of the rural dwellers sourced their income mainly from agriculture and allied businesses, while the least (8.61%) were salary earners from the private sector.

Table 3. Distribution by Education and Income

| Variable | Categories | Frequency | Percentage |
|---|---|---|---|
| Education (years) | 6-11 | 691 | 22.20 |
| | 11-16 | 2,421 | 77.80 |
| Source of income | Agriculture and allied activities | 1,876 | 60.28 |
| | Artisans | 672 | 21.59 |
| | Private sector | 268 | 8.61 |
| | Public Sector | 296 | 9.51 |
| Annual income (₦) | ≤ 150,000 | 1,711 | 54.98 |
| Mean = 505,722.70 | 150,001 - 750,000 | 1,236 | 39.72 |
| Minimum = 13,502.91 | 750,001 - 1,350,000 | 85 | 2.73 |
| Maximum = 5,814,709.21 | ≥ 1,350,000 | 80 | 2.57 |
| Annual per capita income (₦) | ≤ 25,000 | 1,677 | 53.89 |
| Mean = 85,715.71 | 25,001 - 125,000 | 1,267 | 40.7 |
| Minimum = 4,286.21 | 125,001-225,000 | 87 | 2.80 |
| Maximum = 1,256,014.07 | ≤ 225,000 | 81 | 2.60 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

About 22 per cent of the rural dwellers were artisans, and 9.5 per cent were civil servants. This implies that agriculture is a major source of livelihood in rural areas of Nigeria and has contributed significantly to their economic status.

Regarding the annual income in rural Nigeria, the majority (54.98%) of the rural dwellers received an annual income below ₦150,000 (USD 449.10), while the least had an annual income of ₦1,350,000 (USD 4,041.92) and above, as shown in Table 3.

The average annual household income in rural Nigeria was ₦505,722.70 (USD 1,514.14) with a minimum of ₦13,502.91 (USD 40.43) and a maximum of ₦5,814,709.21 (USD 17,409.31). This signifies a wide variation in rural household income. The rural households had an average annual household per capita income of ₦85,715.71 (USD 256.63), which suggests a low annual per capita income in rural Nigeria. The minimum annual per capita income of rural households was ₦4,286.21 (USD 12.83) and a maximum of ₦1,256,014.07 (USD 3,760.52), which also suggests a wide variation in their income.

**Income inequality and income shares of rural households before and during the democratic era**

Table 4 shows the estimated values of the Theil index and Gini coefficient, which compare the income inequality before and during the democratic era in rural Nigeria. The Gini coefficient of 0.5 implies an extremely high-income inequality among the rural populace in Nigeria before democracy, while 0.44 implies a high inequality during democratic era. Also, the theil index of 0.39 before democracy and 0.32 during democracy showed some level of high-income inequality among rural households. Although these values are still on the high side, there is a tremendous improvement in rural household income inequality as the Gini coefficient and theil index reduced by six per cent and seven per cent, respectively. Thus, both indexes agree that inequality was higher before the democratic era than during the democratic era, which indicates the contribution of democracy to reducing income inequality. The high-income inequality reported in this study corroborates previous findings that rural households, both in developing and developed countries, had a high-income inequality [1, 3, 8, 20, 24, 26, 27, 32].

Table 4. Gini index and theil index before and during the current democratic era

| Metrics | Pre democratic era | Democratic era |
|---|---|---|
| Gini index | 0.50 | 0.44 |
| Theil index | 0.39 | 0.32 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

Table 5. Income shares (%) before and during the current democratic era.

| **Metrics** | | **Pre democratic era** | | **Democratic era** | |
|---|---|---|---|---|---|
| **Decile** | **Class** | **Decile share** | **Share of classes** | **Decile share** | **Share of classes** |
| 1st decile | Lower Class | 1.86 | | 2.76 | |
| 2nd decile | Lower Class | 2.84 | | 3.90 | |
| 3rd decile | Lower Class | 3.91 | 8.61 | 4.78 | 11.35 |
| 4th decile | Middle Class | 5.45 | | 5.72 | |
| 5th decile | Middle Class | 6.79 | | 6.83 | |
| 6th decile | Middle Class | 7.51 | | 7.96 | |
| 7th decile | Middle Class | 9.16 | 28.91 | 9.75 | 30.26 |
| 8th decile | Upper Class | 12.05 | | 11.76 | |
| 9th decile | Upper Class | 16.16 | | 15.54 | |
| 10th decile | Upper Class | 34.27 | 62.48 | 31.09 | 58.39 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

Table 5 shows the income shares of rural households before and during the democratic era. Before the democratic era, the lower class (lowest 3 deciles of the population) controlled

8.61% of the total income as opposed to 11.35% during the democratic era; the middle class controlled 28.91% before democracy but has increased to 30.26% during the democratic era; and the upper class controlled 62.48% before democracy as opposed to 58.39% during the democratic era (Table 5).
The nation, therefore, had an expanding middle class during the democratic era.
The reduction in income inequality could be a result of some policies and programmes put in place during the democratic era, such as the National Poverty Eradication Program, the National Economic Empowerment and Development Strategy, and the Presidential Youth Empowerment Scheme. Naseer and Ahmed [20] also reported that income inequality reduced due to government's policies and program.
The decrease in income inequality during the democratic era was also evident by the inward movement of the Lorenz curve towards the line of equality (Figure 2). The pink line in Figure 2 represents the inequality curve of the pre-democratic era, while the blue line represents the inequality line of the current democratic era. Thus, income inequality decreased by 6% between the pre-democratic and democratic eras. These results imply that the democratic era has reduced income inequality in the nation and also increased the share of income of the lower class and middle-class rural households, thereby reducing the high-income share among the upper class.

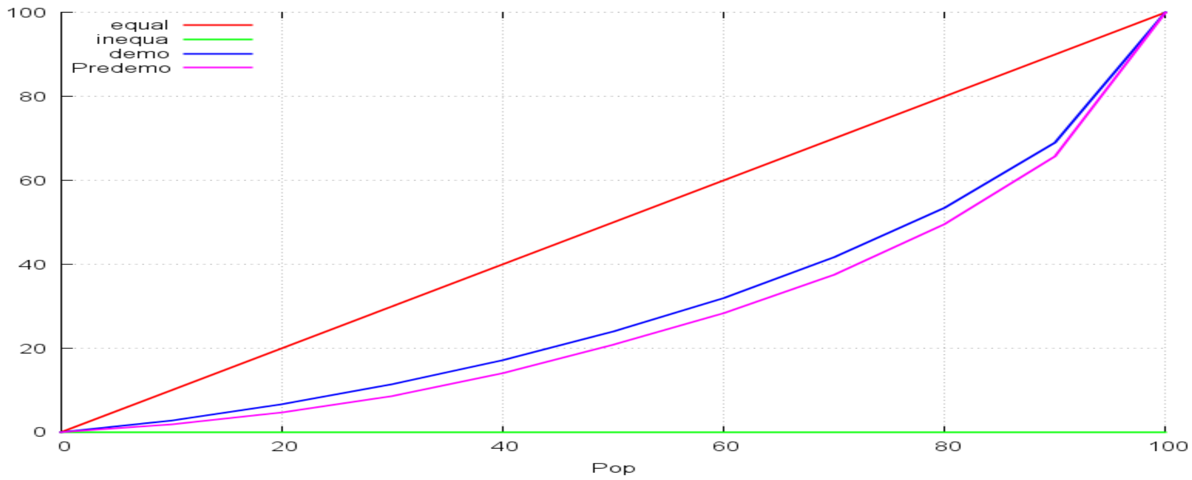


Fig. 2. Lorenz curve for the pre-democratic and democratic era
Source: Authors' Computation based on GHS (2019) and NCS (1996).

**Contribution of socioeconomic factors to income inequality**

Table 6 shows the outcome of regression-based inequality decomposition, which shows the contribution of socioeconomic factors to income inequality in Nigerian rural households. The result of the coefficient of determinants (R-square) was 0.548, which implies that 54.8% of the variations in income were explained by the independent variables included in the model. Among the socioeconomic factors in the model, the years of education contributed the most to total inequality (23.5%). The dependency ratio had a negative coefficient and contributed -15.3% to income inequality. Household size contributed 6.2% to income inequality, age had a negative coefficient, thereby contributing -0.59% to total inequality, the gender of the household head contributed 0.03% to overall income inequality, and 0.1% of income inequality was contributed by marital status.
Income flow to the household as a result of household head age and dependency ratio (which considers the household size with those within the income-earning range) contributed negatively to income inequality, thereby reducing the income inequality in rural households. Considering their major occupation, farming, which is energy-demanding, farmers' strength, productivity,

and income reduce as their age increases [17]. As a result, income inequality between young and old in rural areas exists.

Years of education was a contributing factor to income inequality. Highly educated people have a higher income than those with no or little education [17, 18]. Due to different educational level in rural households and because 18.1 per cent of the respondents were salary earners, the educational qualifications determined their income and caused disparities in their earnings, which led to income inequality. Similarly, education paves the way for information and adoption of innovation among farmers, therefore, leading to high yield and income among farmers with higher educational status and vice versa [4,10]. This thus led to income disparity among farmers of different levels of educational status. Naseer and Ahmed [20] found a similar result that the level of education contributed to income inequality in Pakistan.

Household size also played a significant role in income inequality. This is because larger household sizes impose a higher responsibility on the household heads, thereby reducing the per capita income in the household. Thus, a lower household size will reduce income inequality in rural areas. This corroborates Akin-Olagunju and Omonona [5] and Usman et al. [32], who reported that household size had a positive effect on income inequality.

Marital status also contributed to income inequality among rural households. Akin-Olagunju and Omonona [5] also reported that marital status contributed to income inequality in Nigeria. A married household head has more responsibilities than a single household head as a married household head has a relatively larger household size, which thus reduces the per capita income in such a household. whereas single household heads have a higher per capita income. This thus caused income inequality among rural households.

The gender of the household head had a positive influence on rural households' income inequality. This suggests that the gender differences in household heads increase income inequality. This could be a result of higher income among male-headed households than female counterpart, thus creating income inequality among them. This corroborates Oyekale et al. [25], Ayinde et al. [7], Naseer and Ahmed [20], and Usman et al. [32], who found that gender had a positive and significant influence on income inequality.

Table 6. Factor inequality weight of the variables for rural households

| Variables | Coefficient ($\beta_j$) | Standard deviation of $X_j$ | Correlation of $(X_j, \ln Inc)$ | Factor inequality weight of $S_j$ |
|---|---|---|---|---|
| Age | -0.017 | 14.536 | - 0.024 | 0.0059 |
| Gender | 0.042 | 0.385 | 0.047 | -0.0003 |
| Years of education | 0.344 | 2.491 | 0.336 | 0.235 |
| Dependency ratio | - 0.020 | 0.986 | -0.288 | 0.153 |
| Household size | 0.001 | 3.225 | 0.264 | 0.062 |
| Marital Status | 0.013 | 0.52 | 0.003 | 0.001 |
| $R^2$ | | | | 0.548 |

Source: Authors' Computation based on GHS (2019) and NCS (1996).

## CONCLUSIONS

With the current democracy, rural households' income inequality has been reduced by 6%, which could be as a result of some policies and programs put in place during the democratic era. This shows some improvement in income distribution and the enjoyment of the governance dividend by the citizens in rural areas of the country. Although income inequality in rural Nigeria is still relatively high, Also, the share of middle population has increased by 1.35% between the pre-democratic era and the democratic era. The electioneering process in democracy has forced politicians, especially lawmakers, to implement agricultural projects such as the distribution of farm inputs in their rural constituencies to garner the votes of the rural electorates. Whether done with good intentions or not, it has helped to reduce income inequality in rural areas when compared to the military regime when people have no say in who their leaders are. Furthermore, the income inequality contributing factors are years of education, household size, gender, marital status, age, and dependency ratio. It is worth noting that among the income inequality contributing factors, years of education contributed the most. The study also found the dependency ratio to have much more of an impact on inequality than household size.

For the government and development partners to achieve more of their aims, especially in reducing income inequality in rural areas, there is a need to gear programmes and policies in the rural areas to boost the education system and empower women so that they can contribute significantly to household income and needs. This can be achieved through the provision of incentives to rural dwellers to pursue education and by giving women access to production resources such as land, farming inputs and credit facilities. Empowering women will go a long way toward reducing income inequality in rural households. Deepening democracy in Nigeria has the potential to further reduce income inequality. Therefore, the government should further strengthen democratic institutions to ensure that the current democratic era yields more benefits to the populace and not truncate it.

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# RESOURCE USE EFFICIENCY OF TEMPERATE SILK COCOONS IN NORTH-WESTERN HIMALAYAN REGION OF KASHMIR VALLEY, JAMMU AND KASHMIR, INDIA

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***Abstract***

*Sericulture's resource efficiency are critical for long-term growth and contributes greatly to Kashmir's rural and urban economies for sustainable livelihood and inclusive growth. Mulberry plantations, silkworm rearing, reeling, and silk textile manufacturing is all part of the silk farming process. The primary goal of this research was to determine the socioeconomic features of silk worm rearers, as well as to analyze and assess the resource use pattern of silk cocoon in Kashmir valley. The study is empirical in nature, and data was collected from 334 respondents in silk farming-rich zones such as Anantnag and Baramulla in 2021-22 utilising a pre-tested structured interview schedule and purposeful stratified random sampling. Descriptive statistics and Cobb Douglas production function analysis were used to conduct this study's analysis. The results showed that generally, silk worm rearers in Baramulla and Anantnag were inefficient in their use of resources avail-able to them. Silkworm seed, mulberry leaves, silkworm rearing sheds were underutilized, while labour, disinfectants were over utilized by the farmers. The results further showed that sericulture farmers in Anantnag and Baramulla exhibit increasing returns to scale, indicating that the famers can increase their output by increasing the use of some of the key resources. The finding revealed that silk rearers in Baramulla and Anantnag districts of Kashmir valley were experiencing increasing return to scale. As the total of calculated coefficients of significant variables was found to be more than unity, (1.32).MVP indicates that there is still scope to invest in the study's elements in order to attain the best resource combination and profit maximisation. Incentives and techniques targeted at encouraging farmers to enhance silk cocoon production, such as better government administration of the current subsidy programme and efficient input delivery through sericulture-based centres to ensure silk worm farmers have easy access. This research proved that an intense integrated approach to balanced regional development can help the Kashmir valley's silk industry survive.*

***Key words***: *silk cocoons, silk worm rearers, Cobb Douglas production function, marginal value product, Kashmir valley, India*

## INTRODUCTION

Using local resources for agricultural sustainability has received a lot of attention in recent years. Proper exploitation and management of local resources, as well as the development of varied agro-based firms, have the ability to create a regional balance between the rural and urban sectors, as well as provide a sustainable source of income [7]. The expansion of the Kashmir sericulture is dependent on the natural environment. The mulberry crop, which is directly responsible for the generation of silk cocoons, is the foundation of sericulture. The cultivation of silk-producing organisms is known as silk farming. The phrase is derived from the Greek words sericos, which means silk, and culture, which means upbringing. Mulberry plant cultivation, silkworm rearing to generate silk cocoons, cocoon reeling to untwist silk filament, yarn manufacture, weaving, and silk fabric processing are all included [26, 31, 23]. It generates income for farm households in Kashmir throughout the year, primarily during the spring and autumn seasons [22, 43, 28].

Sericulture is a low-capital-intensive agro-based activity that generates a steady stream of revenue throughout the year in rural India. It provides a solid livelihood to more than 7.5 million people in 79 thousand villages across India, as well as other activities [25, 13].

In the midst of escalating poverty and inequality, sericulture has emerged as one of the most promising and perfect rural income-generating sectors, thanks to its short rearing period and high employment potential with quick turnover. It unmistakably offers a stable income for a huge number of marginal farmers and craftspeople [14]. Mulberry silk is a well-known variety of silk in the textile industry [3, 6]. It is a substantial economic subsidised income-generating activity for rural people in mountainous locations [53, 4] and provides employment in industries that are important in the metropolitan economy. China, India, Uzbekistan, Thailand, and Brazil are the world's top silk producers [14, 36, 37, 39].

In 2019, the International Sericultural Commission (ISC) released a study on sericulture producers and consumers. The United States of America (USA), Switzerland, the United Kingdom, and Germany are the top silk consumers and importers in Europe. Brazil produces 610 metric tonnes of silk yarn every year on an average of 2.6 hectares, boosting the livelihoods of rural families [2]. In 2017, China produced 145,000 metric tonnes of silk, whereas India produced 31,900 metric tonnes. In compared to India's 5.60% growth rate, Japan (7.31%), Brazil (3.82%), Thailand (%), and Korea (1.17%) all give 16.10% [9]. Sericulture has been promoted extensively in various parts of Africa, South Asia, and Latin America in order to improve women's empowerment and gender equality, as well as contribute to sustainable development goals [21]. It is thought to be a lucrative business with a lot of job opportunities [24, 17, 52, 35, 38].

Silkworms are responsible for the production of mulberry silk (*Bombyx mori*). Silkworms consume mulberry leaves and produce silk cocoons in 28 to 30 days, after which they spin the cocoons. Finally, the silk cocoons are purchased and spun into silk yarn by the reelers. J&K bivoltine silk is of high quality due to its agro-climatic conditions, which improves the economic status of sericulture producers and ensures long-term sustainability in the pre-cocoon and post-cocoon sectors.

Sericultural development strategy for underdeveloped countries should be oriented toward enhancing the productivity of land under cultivation while lowering costs and boosting input efficiency while causing little or no harm to humans and the environment. To decrease land degradation and input misuse, the primary requirement is to promote a healthy soil-plant-environment system. Modification of current farming systems in the field of soil nutrient restoration to encourage the adoption of Sericultural farming is a novel strategy for promoting eco-friendly farming. Reducing environmental consequences also contributes to well-being that is not derived from the market economy, such as the quality of life that comes with living in a healthy, appealing environment. Furthermore, boosting resource efficiency can raise industry's competitiveness, create opportunities, promote innovation, boost sectors like recycling and resource recovery, and assist assure the secure supply of critical resources. With the shortage of available agricultural land growing, improving crop output faces a new challenge: ensuring that land becomes more productive. This is where resource efficiency in our agricultural and food systems becomes important [45].

**Literature review**

Sericulture is an economic activity that comprises the cultivation of mulberry bushes and the raising of silkworms to generate silk threads utilising agricultural labour [16]. Sericulture is split into two categories: farm and industry. Growing silkworm feeding plants and rearing silkworm to generate silk cocoons are both part of the farm industry. The industry sector includes reeling, twisting, dyeing, printing, finishing, and knitting [44, 49, 10].

Silk has a bright future ahead of it and could be revolutionary in the next decades. Silk is now used in a variety of fields, including nutrition, cosmetics, biomaterials, pharmaceuticals, bioengineering, biomedicine, vehicle manufacture, home building, crafts, and the arts, despite its historic use in textiles. Increased stakeholder awareness, entrepreneurial experience sharing, and consumer accessibility are all required as global demand grows [37, 39, 6]. Sericulture, as a cottage, agro, and forestry-based industry, has been shown to improve sustainable livelihood. With all of the aforementioned characteristics of the silk industry, sericulture is an ideal industry for a long-term future [18, 19].

Mulberry silk, Tasar silk, Eri silk, and Muga silk are all produced in India's silk industry, which is world-renowned. India is the world's second largest producer of silk, with 31,906 metric tonnes [1, 9] and 15% of global raw silk output, ensuring the region's long-term prosperity [30]. Geographically, Asia produces the vast bulk of the world's silk, accounting for over 95% of total output. With an annual production of 142,005 metric tonnes, China is the world's biggest silk producer [21]. Mysore, Andhra Pradesh, Tamil Nadu, West Bengal, and Jammu & Kashmir are the major mulberry sericulture producing states of India, accounting for 98.5% of the country's silk production [1, 9]. India needed 27,005 metric tonnes of raw silk, but only produced 19,696 metric tonnes and imported 8,000-9,000 metric tonnes from China [5]. Currently, the consumption of silk products in industrialised nations is increasing, resulting in strong demand on the worldwide market and playing an important rolein foreign exchange earnings for developing countries around the world, resulting in the transition from sericulture to manufacturing [37]. On a commercial basis, Brazil is the fifth largest silk cocoon production [31]. Brazil shipped around 109 million tonnes of textiles and clothing and nearly 686 million tonnes of other goods in the first half of 2019 [11]. The silk industry's economic viability has a considerable impact on its long-term viability [23, 40].

Sericulture is a viable rural industry that provides remunerative work and significant opportunities for increasing human resource employability [27, 51, 50]. Silkworm seed, mulberry leaf, and labour have favourable and substantial associations with cocoon formation, according to [29, 41, 42]. [32] investigated the factors influencing cocoon production indrought prone region of Andhra Pradesh. [48] investigated resource efficiency in the Himachal Pradesh district of Bilasapur and the resource productivity of silk cocoon production. To the best of our knowledge, no such comprehensive study on the resource efficiency of silk cocoons has been undertaken in the Kashmir valley.

This research examines the resource efficiency of silkworm rearers in the viable regions of Anantnag and Baramulla, which is critical for policymakers to consider when developing policies to improve silk cocoon growth and productivity in the Kashmir valley. The major goal of this study was to look at the socioeconomic factors and resources that influence silkworm rearers'/farmers' ability to produce silk cocoons in Kashmir.

## MATERIALS AND METHODS

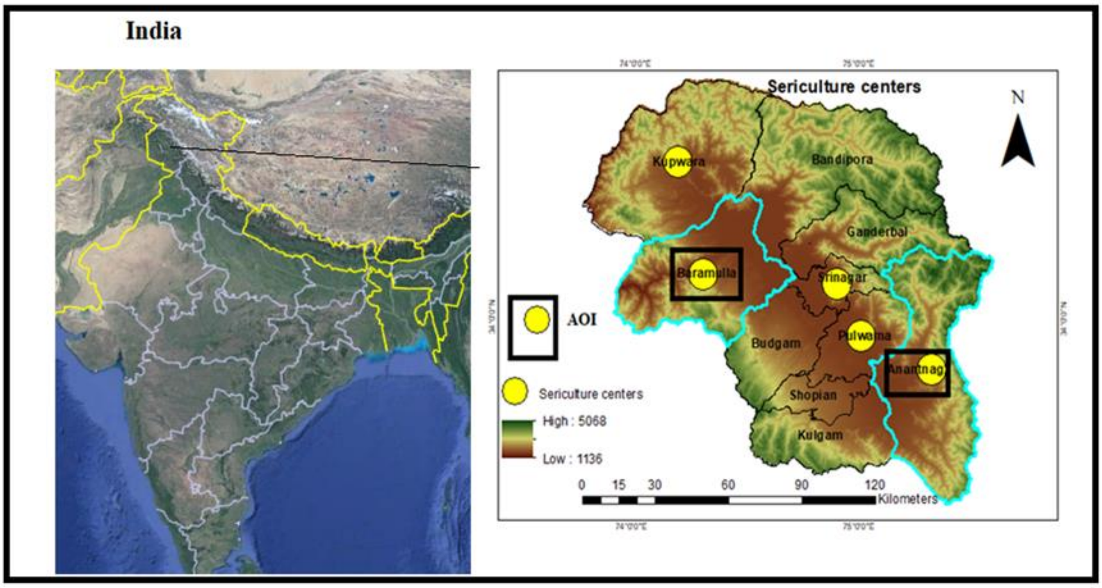
### Study area

The Kashmir valley, which spans 15,220 square kilometres and located between the Pir Panjal and the western extremity of the Great Himalayan peaks, is a deep asymmetrical basin and mesogeographical region. The Pir Panjal Range to the Southwest and the main Himalayan range to the Northeast define the Kashmir valley, which stretches from 35° 22' to 34°43' N and 73° 52' to 75°42'E. It's about 135 kilometres long and 32 kilometres wide, and it's drained by the Jhelum River.

Kashmir valley is also known for its agricultural products such as fruit, vegetables, saffron, herbs, and minerals, as well as rare handicrafts such as silk carpets, shawls, and the finest embroidery. Mulberry trees, which are abundant in the Valley and form the backbone of the silk industry, have a diverse range of flora and fauna. Over 70% of the population is employed in agriculture and allied sectors like as sericulture, animal husbandry, and apiculture. The Twelfth Five-Year Plan (2012-2017) in J&K implemented an Industrial Policy that focuses on silk textile industries, silk carpet weaving, handloom and handicraft sectors, Khadi and village industries, and promotes green economy and eco-friendly firms.

Kashmir valley has a temperate environment with seasonal weather. The temperature ranges from 10°C in the winter to 39°C in the summer, with an average annual precipitation of 75cm [47, 15]. Weather has an impact on both mulberry cultivation and silkworm rearing. Mulberry cultivation and silkworm rearing are both affected by the weather. According to the World Bank's 2021 income classification, sericulture plays a crucial role in the Kashmir valley's subsistence options, which are typically landless and marginal. The Kashmir Valley's Himalayan topography is ideal for sericulture growth and development, allowing rearers to achieve silk farming sustainability [20].

The research area's most important sericulture centres are Anantnag and Baramulla in Kashmir Valley, which contribute the most silk cocoon production in Kashmir Valley [33, 34]. Sericulture helps to the development of a well-balanced economic sector in Kashmir's rural economy. Due to the geo-economic feasibility of sericulture, the union territory of Jammu and Kashmir has been able to increase its output of silk cocoons and yarn. According to the evaluation index, the future growth plan should concentrate on regional expansion of sericulture in economically viable locations, particularly in the districts / sericulture centres of Baramulla and Anantnag [34] (Map 1).




Map 1. Location map of study area
Source: Prepared by authors Arc GIS 10.4.

The information for this proposed study was gathered from both primary and secondary sources. Observation, personal interviews, targeted groups, debates, and other participatory community-based approaches were employed to collect primary data. Fieldwork was to be carried out in the Kashmir valley's Anantnag and Baramulla districts (2021). Aside from primary statistics, secondary data from the District Sericulture Offices in Anantnag and Baramulla (2021) revealed that silk growing employs 1,210 and 1,340 rearers, respectively. Anantnag and Baramulla represent the southern and northern parts of Kashmir, respectively, where the most silk cocoons are produced (Srinagar, DSO, 2021) [12]. In the Kashmir valley, Anantnag and Baramulla are considered prospective areas for sericulture development. The sampling strategy utilised in this study was purposive stratified random sampling, in which two sericulture-rich districts were chosen to represent the northern and southern halves of the valley, respectively, with an acceptable number of villages. A systematic questionnaire was used to collect primary data on silk cocoon output from 334 silkworm rearers.

The sample size determination formula developed by Barlett et al (2001) [8] was utilised in this investigation to determine the suitable sample size. The following equations were used to select the sample size consisting of 334 silkworm rearers for the current investigation.

n $= t^2(p)(q)/d^2$ ......................... (1)

where:
n = sample size,
t = value for selected alpha level of 0.025 in each tail = 1.96,
p = proportion of population engaged in silk cocoon production activities,
q = proportion ofpopulation who do not engage in silk cocoon production activities, and
d = acceptable margin of error for proportion being estimated = 0.05
n =1.962 $\times 0.5 \times 0.5/0.05^2$ = 334 rearers.

**Cobb Douglas production function**: Cobb Douglas production function was used to measure resource use efficiency of silk cocoons in potential sericulture centres of Kashmir valley, namely Baramulla and Anantnag, where sampling survey was conducted using a pre-structured questionnaire, to determine the effect of various independent variables on the output of silk cocoons.

The Cobb Douglas production is fitted in silk cocoons
Y = Production of Silk cocoons (Kgs)
X1 = Mulberry leaf production (Kgs),
X2 = silkworm seed (ounces)
X3 = Labours (mandays/yr.),
X4 = Disinfectants (Kgs/yr.)
X5 = Training/Experience of silkworm rearers
X6= Silkworm Rearing sheds,
X7= Family farming

Y= $b_0 X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} e^{\mu}$ ........................................................... (2)

Apply Log from both sides:

$Log\ Y = Log\ b^0 + b_1 LogX_1 + b_2 LogX_2 + b_3 LogX_3 + b_4 LogX_4 + b_5 LogX_5 + b_6 LogX_6 + b_7 LogX_7 + \mu$ ............ (3)

**Marginal value product**

The estimated coefficients were used to compute MVP. We can assess the relative importance of factors of production by studying marginal value product. Marginal value product of $X_{i,}$
I.e. for the i input, it is estimated by the following formula (equation 4)

MVP $= bi \times \frac{GM(Y)}{GM(XI)} \times Py$ ……………………………………………. (4)

where:
GM (Y) and GM (Xi) represents the geometric means of output and input, respectively,
$b_i$ is the regression coefficient of ith input and
$P_Y$ is the price of output.
The efficiency of input use was estimated using the following equation (5)

r = MVP/MFC …………………………… (5)

where:
r is the efficiency ratio,
MVP is the marginal value product of variable input and
MFC is the marginal factor cost (price per unit input).

Based on economic theory, a firm maximises profit with regard to resource use when the ratio of marginal return to the opportunity cost is one. The value of r less than unity indicates excess use of resources (there exist scope for reduction). If r is greater than one, it indicates underutilisation of resource (there is scope to increase. If r is equal to unity, it indicates optimum utilisation of resource [46].

r = 1, It denotes that the input was effectively utilised

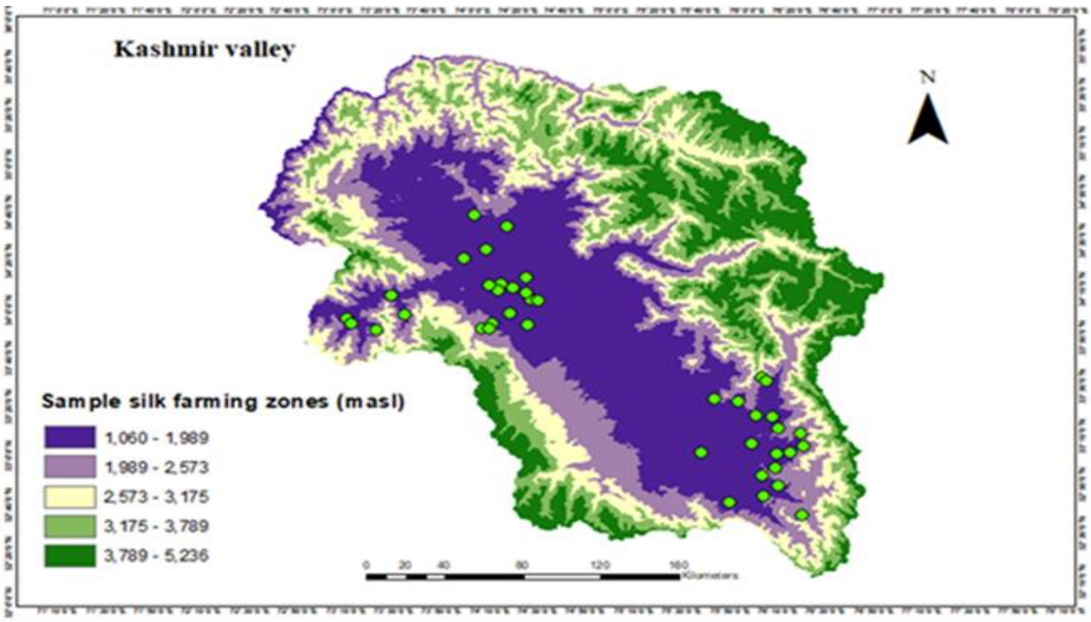
r > 1, It means that the input was underutilised, and that increasing the use of that resource would enhance both output and profit.

r < 1, It means that the input is overused, and that if less of it is used, both output and profit would be maximised.

## RESULTS AND DISCUSSIONS

### Socio- economic characteristics of silkworm rearers

The socioeconomic characteristics of silkworm rearers interviewed in the study are shown in Table 1. Table 1 also includes descriptive statistics on the characteristics of silk cocoon farmers. Males account for 25.15% of silk cocoon farmers in the sample, while females account for 74.85%. Because silk cultivation is more popular in indoors, it obviously means that more women are involved in it. According to the table, 37.43% of the silk rearers are between the ages of 40-50. This data clearly shows that the bulk of silkworm rearers engaged in sericulture activities belonged to old adults. The age factor is thought to be crucial in the farming experience of silkworm rearers.In terms of occupation, 86.50% of farmers were involved in both sericulture and agricultural operations, whereas 13.50% were only involved in sericulture. Agricultural crops are cultivated for food, while sericulture is grown for profit. In terms of literacy, 37% of farmers had completed secondary school, indicating that silk worm farmers have a high degree of literacy. This factor will give technology adoption and spread an additional boost. As we all know, experience makes a man perfect, thus we chose farm experience as one of the indicators to learn about the farmers' experience in the research area's sericulture activity. The vast majority of farmers (29%) have 11 to 15 years of experience on the farm.




Map 2. Sample silk farming surveyed villages of study area
Source: Field survey (2021-22).

When it comes to the sort of silkworm rearers family, the greater the family, the more family labour will be available for sericulture and agriculture operations, which are both labour intensive. Land is a crucial factor for understanding sericulture operations and the extent of farmers' land holdings in the research area.

The data shows that marginal rearers account for 85.32% of the 334 respondents with land holdings of less than 1 hectare and 14.67% of progressive rearers with land holdings of more than 3 hectares. Sericulture centres provided 1 ounce of silkworm seed to marginal rearers and 2 ounces of silkworm seed to progressive rearers. It appears that the majority of silk farmers fall into the marginal category, with the remaining belonging to progressive farmers. This clearly demonstrated that marginal farmers in Kashmir valley are primarily involved in silk farming.

Table 1. Socioeconomic characteristics of silkworm rearers in the study area (Anantnag and Baramulla)

| Variable | Frequency | % | Mean | Standard deviation |
|---|---|---|---|---|
| **Gender** | | | | |
| Male<br>Female<br>Total | 84<br>250<br>334 | 25.15<br>74.85<br>100.00 | - | - |
| **Age group (years)** | | | | |
| < 30 | 90 | 26.95 | 24.75 | 5.10 |
| 30-40 | 125 | 16.46 | 35.20 | 4.15 |
| 40-50 | 55 | 37.43 | 46.10 | 4.90 |
| 50-60 | 40 | 11.97 | 54.40 | 5.15 |
| >60 | 24 | 7.19 | 63.60 | 3.80 |
| Total | 334 | 100.00 | | |
| **Occupation** | | | | |
| Sericulture | 44 | 13.50 | | |
| Sericulture and Agriculture | 290 | 86.50 | | |
| Total | 334 | 100.00 | | |
| **Education** | | | | |
| Illiterates | 80 | 23.95 | | |
| Primary | 100 | 29.94 | | |
| Secondary | 125 | 37.42 | | |
| Higher secondary | 20 | 5.98 | | |
| Above Higher secondary | 9 | 2.69 | | |
| **Farm experience (yrs.)** | | | | |
| 5-10 | 90 | 26.94 | 7.25 | 2.0 |
| 11-15 | 100 | 29.94 | 13.30 | 2.10 |
| 16-20 | 95 | 28.44 | 17.20 | 2.65 |
| 20-25 | 40 | 11.97 | 23.40 | 1.90 |
| 26-30 | 9 | 2.69 | 27.30 | 2.50 |
| **Type of Family** | | | | |
| Joint family | 38 | 11.37 | | |
| Nuclear family | 296 | 88.62 | | |
| **Land holding size of rearers (ha)** | | | | |
| Marginal (<1) | 285 | 85.32 | | |
| Progressive (>3) | 49 | 14.67 | | |
| **Silk worm seed taken by rearers (ounces)** | | | | |
| Marginal 1 | 285 | 1 ounces | | |
| Progressive 2 | 49 | 2 ounces | | |

Source: Field survey, 2021.

Silk Cocoon production was treated as a dependent variable, with factors such as mulberry leaf, silkworm seed, disinfectants, labour, farmer experience/training, silkworm rearing sheds, and family farming utilised to produce cocoons regressed. With a value of 0.83, the coefficient of multiple determinations ( $R^2$ ) was significant, indicating that the factors included in the function could explain 83% of variation in cocoon production. The regression constant was positive. The regression coefficient of variable such as mulberry leaf was positive and significant at one per cent level with the value of 0.345 per cent implying that one per cent increase in the above said variable from the existing mean level would increase the production of cocoon by 34.5%. The regression coefficient of the variables such as labour, silkworm rearing sheds, family farming, training/experience of silkworm rearers, disinfectants were found to be non-significant.

Mulberry cocoons were the principal crop produced by silk worm rearers in the research area, which was influenced by a number of factors. Quantifying the degree of correlation and cause-and-effect link between cocoon production on the one hand and multiple factors impacting cocoon formation on the other is critical from a policy standpoint. This type of exercise could aid policymakers and sericulturists in focusing on the strategic variables. The purpose of this study is to look at the input-output relationship for cocoon production in the study area. Cobb-Douglas production function with seven explanatory variables was used. The results for full model and stepwise function are given in Table 2 and 3. The results of production function with all variables (Table 2) showed that only silk worms seed (X2) and numbers of mulberry feedings per day (X1) were the significant variables in affecting the cocoon production. The regression coefficients of Cobb-Douglas production function are the direct measures of elasticities of production for the inputs.

The results of the stepwise production function shown in Table 2 demonstrated that the most important variable determining cocoon generation was silk worm seed. This variable's coefficient revealed that a 1% increase would result in a 0.558 percent increase in cocoon production. The amount of mulberry feedings delivered to the silk worms per day. This variable reveals that a 1% increase in silk worm feeding frequency can result in a 0.345 percent increase in cocoon output. This variable shows that 1% increase in the frequency of silk worms feeding may bring 0.345 per cent increase in the cocoon production. During the survey period, it was found that feeding silk worms fresh mulberry leaves a number of times considerably aided their growth and maturity. The returns to scale for these variables were found to be more than unity, indicating that there is scope to improve the usage of these variables in silk cocoon manufacturing. Only two variables, silk worm seed and daily frequency of mulberry feeding to worms, were shown to have a significant impact on cocoon production, implying that increasing the use of these inputs might increase the amount of cocoon in the research area.

Table 2. Factor inputs impact on silk cocoon production in the studied area

| **Variables** | **Regression coefficient** | **Standard error** |
|---|---|---|
| Intercept | 2.143 | |
| Mulberry leaf | 0.345 | 0.024 |
| Labour | 0.176 | 0.038 |
| Silkworm seed | 0.558 | 0.143 |
| Disinfectants | 0.018 | 0.021 |
| Training/Exp | 0.067 | 0.042 |
| Family farming | 0.025 | 0.013 |
| Silkworm rearing sheds | 0.241 | 0.037 |
| Coefficient of determination | 0.83 | |
| Observations | 334 | |
| F-Test | 4.59 | |
| P-value | 0.007 | |

Source: Field survey (2021-22).

Table 3. Allocative efficiency of factor inputs in silk cocoon production using MVP/MFC ratio in the study area

| **Variables** | **MVP/MFC** | **Decision rule** |
|---|---|---|
| Mulberry leaf | 1.472 | under- utilised |
| Labour | 0.853 | over-utilized |
| Silkworm seed | 1.19 | under- utilised |
| Disinfectants | 0.678 | over-utilized |
| Silkworm rearing sheds | 1.13 | under- utilised |
| Return to scale | 1.32 | under -utilised |

Source: Field survey (2021-22).

It is clear from Table 3 that the MVP to MFC ratio was more than 1 for mulberry leaf (1.472), silkworm seed (1.194), and silkworm rearing sheds (1.19) which indicates underutilisation of resources. Thus results indicated that scope for reallocation of expenditure among these resource and optimize silk cocoon production. There exists scope for higher use of these resources from their existing level to reach optimum production of silk cocoon. The results of the present study show that the MVP to MFC was less than 1 for labour (0.853) disinfectants (0.946) were overused in silk cocoon production as the ratio of MVP to MFC was less than unity. There is a need to reduce the use of these resources to attain optimum silk cocoon production. The returns to scale calculated for silk cocoon rearers in the study area reveal increasing returns to scale. The results suggest that silk cocoon farmers could enlarge their productivity, given their disposable resources. That is, silkworm farmers can increase their silk cocoon output by employing more of the resources (silkworm seed, mulberry leaves and silkworm rearing sheds) employed in silk farming. Return to scale analysis in the present study showed value of 1.32 which indicates increasing return to scale in the study area and this finding was in line with the findings of [48 and 26].


Photo 1. Mulberry nurseries, Farmer pruning mulberry branches, Silkworms feed on chopped mulberry leaves, Silk cocoons in living room, silk cocoon trays, family farming, rearing sheds, Reeled mulberry silk. Cocoon marketing at sericulture centres.
Source: Field photographs of surveyed villages, 2021-2022.

## CONCLUSIONS

In general, quantities of silkworm seed, mulberry leaves, and silkworm rearing sheds should be raised for maximum resource usage in silk cocoon production while labour and disinfectants should be minimised in the districts of Anantnag and Baramulla. For silkworm rearers to attain resource usage efficiency, incentives and tactics aimed at encouraging them to use hybrid silkworm breeds, experience/training of silkworm rearers, family farming, and rearing sheds are recommended. Extension officers should encourage silk rearers to join farmer-based organisations in areas where they already exist by explaining the benefits of such groups to the farmers. They should support silk rearers in forming such groups in regions where none exist, since this maintains the region's sustainability and plays a critical role in boosting resource use efficiency and silk cocoon productivity in the Kashmir valley.

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# ANALYSIS OF THE QUALITATIVE PARAMETERS OF THE MAIN CROPS PRACTICED AT AN AGRICULTURAL COMPANY

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***Abstract***

*In this paper, the variation of the quality indices of the seeds obtained in the period 2021-2022 at an agricultural company is tracked and the factors responsible for the defects found were analyzed. The company under study is based in Mânăstirea commune, Călărași county and has an area of 183.55 ha. From the crops practiced by the society, we analyzed the quality parameters of wheat, corn and barley, the main crops practiced. We carried out an analysis of the quality of the cereals sold within the company, following the values of the most important selection criteria, based on the analysis bulletins owned by the analyzed company. Almost all the qualitative parameters were included within the norms stipulated by STAS, there being small excesses in the case of some, which led to the inclusion of the barley obtained by the company in the grade 2 category.*

***Key words****: qualitative indices, wheat, barley, parameter, corn*

## INTRODUCTION

Product quality indicators are quantitative expressions of its characteristics [2]. They are used to determine seed quality certification. This represents a set of control operations and verification in the main phases of the multiplication, conditioning, packaging, labelling and sealing process, which ensure that products, processes and services comply with specific technical rules and norms [8]. In general, this consists of: field inspection of seed crops to establish the biological value of seeds in terms of identity, authenticity, varietal purity and phytosanitary status; survey control at the main moments of the harvesting, transport and processing process; determining the technical quality conditions of the seed, including physical purity, germination, sanitary condition; sanitary control regarding the absence of harmful quarantine organisms, which is carried out directly in the field or through samples analyzed in the laboratory by the phytosanitary authority, which issues the finding documents, as well as the verification of varietal authenticity and purity in pre- and post-control, through appropriate testing methods and techniques in the laboratory or in control plots [3]. The presence of certain pests or objects of phytosanitary quarantine in the field or in the seed batch, or the presence of certain diseases that lead to affect the productivity of crops intended for seed production, is strictly prohibited [11].

Determining seed quality is important because cultivated seeds have different uses. Depending on the indications they obtain following some analyses, they get a certain use. Grains with indices that do not meet the standards are generally used for animal feed or go to export, but at a lower price. When it is intended that the grown lots are destined back to sowing, but also for the production of seeds, they must meet very good quality conditions and will go through a process of selection and appropriate treatment for each individual crop. The price of the seeds is determined by the quality that the seeds fulfil [4].

The seeds of each grown species can reach a maximum qualitative level in a complex of conditions that ensure the most favourable interactions between their genetic nature and the large number of variables from the period of their formation on the plant and from the period of harvesting, conditioning and storage [10].

The quality of the seeds is almost maximum at the beginning of full maturity and can be maintained until harvest, if the seeds are not subjected to adverse atmospheric conditions that affect both the integument as well as the embryo. Under conditions of rapid drying and rehydration, cell membranes in the embryo may overstretch and rupture [12].
A disease that frequently affects cereals and results in reduced production is powdery mildew. It appears year after year, especially in wheat, barley and rye crops [9]. If it occurs early, in autumn, it will cause a reduction in the frost resistance of the affected plants, leaf loss and affect root development and twining [7].

## MATERIALS AND METHODS

The Danube River crosses the territory of Mânăstirea commune from km 412 to km 403. Mănăstirea meadow is on the left bank of the Danube, it has relatively uniform widths of 6-9 km and altitudes of 14-15m. The quasi-horizontal relief and reduced fragmentation provide conditions for the practice of agriculture [6].
The company analyzed in the present case study carries out its activity within the radius of Mânăstirea commune, Călărași county and owns an agricultural land of 183.55 ha. It is a limited liability company, the declared activities being part of CAEN category 0111 - Cultivation of cereals (excluding rice), leguminous plants and plants producing oilseeds.
The agricultural products obtained by the company are sold on the domestic market, most of them being sold through an association.
The society is located in an agricultural area with one of the most fertile soils in the region: the soil is a leached chernozem, formed on loess, with appreciable reserves of nutrients and a high degree of fertility [6]. The climatic conditions in which they develop are characterized by relatively low precipitation (450-600 mm), large contrasts between winter and summer (amplitude +25°C) and accentuated evapotranspiration. The parent rock of the leached chernozems consists of loess or leossoid deposits. The chernozems are easy to work, they offer little or medium resistance to soil work, the value of resistance to plowing at optimal humidity being 40-50 Kgf/dm². It lends itself to autumn cereals that capitalize on water reserves accumulated in autumn and winter and reaching full maturity before summer droughts [1].
In order to determine the quality of the obtained seeds, the company has its own laboratory. The analyzed period was 2020-2021, and from the cultivated crops, the quality indices of: wheat, corn and barley were interpreted.
The main parameters monitored in the work were: humidity, impurities, broken grains, sprouted grains, fusariosis attack, gluten and protein content.
The analytical methods for determining the quality parameters are provided in STAS: 1069-67 - determination of impurities, 2522-66 - identification of defects, 6280-66 - determination of grain size, 6124-66 - determination of humidity [2].

## RESULTS AND DISCUSSIONS

In order to obtain maximum and quality harvests, it is necessary to sow seeds of the best quality.
The society studied in this article practices various cultures. The company's culture plan takes into account the importance of crop rotation. It is elaborated for a period of 5 years, the cultures repeating cyclically after this period.
For each of the three crops, we will analyze the main quality indices, to find out the reasons that determined a poor/good grain quality.
Grains are of good, original and commercial quality when they have the typical colour of the grain, are free from unusual odours and parasites at any stage of development, when they meet the minimum quality criteria.
**Analysis of the qualitative parameters of the wheat crop**
According to the analysis bulletins and the detailed grading form for wheat, we have the following indices determined in the laboratory for the 2 analyzed years: humidity, hectolitric

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mass, impurities, broken grains, damaged grains, germinated grains, grains affected by Fusarium, foreign bodies, wet gluten, protein.

Table 1. Analysis of qualitative parameters of wheat crop in the period 2021-2022

| Wheat crop | | | |
|---|---|---|---|
| **Parameters** | **Year 2021 Value (%)** | **Year 2022 Value (%)** | **STAS** |
| Humidity | 11.8% | 12% | 14.5% |
| Hectolitre mass | 75.4% | 74.8% | Min 73% |
| Impurities | 2,9 % | 0.7% | 3% |
| Broken grains | 1.2% | 1.3% | 5% |
| Damaged grains | 2.1% | 2.3% | 5% |
| Germinated grains | 0.1% | 0.1% | 2% |
| Grains affected by Fusarium | 0.12% | 0.1% | Max1% |
| Foreign bodies | 0.7% | 0 | Max 2% |
| Wet gluten | 31% | 25% | Min22 % |
| Protein | 9 | 8.3 % | 10 % |

Source: Quality documents of the company with an agricultural profile [9].

The critical preservation humidity is 14.5 – 15%. At a humidity of 17%, the grains breathe 4–8 times more intensively than at a humidity of 14%. Berries that have reached maturity have higher moisture, but also increased enzyme activity. Sprouted grains have high moisture and high respiration energy, posing a danger to the entire mass of wheat under storage [5].

In the 2 years, the wheat had optimal moisture, which means that it was harvested on time, the grain was not unripe, to retain moisture. The wheat fell into STAS, not needing to go through the drying process.

The higher the hectolitre mass, the better the quality of the wheat. The greater the number of well-formed, healthy, whole-shelled grains, not attacked by insects, the higher the hectolitre mass value will be. big. Impurities in the grain mass can influence the hectolitre mass depending on their nature. The presence of straw, aristas, decreases the hectolitre mass, while the presence of dust and sand increases it.

The hectolitre mass is one of the price setting parameters; it serves as a basis for calculating the sizing of silage cells; it is the basic parameter of flour extractions, with an important role in establishing the yield in flour. The hectolitre mass was higher than that stipulated in STAS, but for a very good quality wheat the hectolitre mass must be over 80.

Impurities are an analysis index that disfavours the seller. A wheat containing many impurities must then go through a selection process, and the price of selecting the wheat will be borne by the seller [3].

The impurities parameter records the normal values, often found following the analyzes performed. Thus the company avoided the selection process, a process that requires time, money, equipment and labour.

At the level of broken grains, of defective grains, we observe that they do not exceed the STAS value provided for by 5%. Broken and defective grains can be due to improper harvesting operation, as well as the occurrence of diseases that do not allow the grain to develop normally.

The sprouted grains have an equal value both in 2021 and in 2022, of only 0.1%, which is due to efficient harvesting operations.

Foreign bodies do not register values above the maximum allowed value, which are 0.7% in 2021 and non-existent in 2022.

Wet gluten is determined because it provides information about the baking properties of the wheat. The STAS value is at least 22%, and from the laboratory analysis obtained it can be observed that it can be used in bakery. Flour with higher gluten content is used for superior baked goods. Low gluten content gives bakery products a smaller volume, flattened shape and a reduced shelf life [8].

Regarding the grains attacked by Fusarium wilt, we note that the values are far below the minimum provided by STAS, of 1%. Fusarium wilt is one of the most widespread and damaging diseases in grains, causing in favorable areas losses of 10-20% of production [11]. The disease occurs with great intensity in our country as well, representing a particular problem in the production of healthy seed. The pathogenic agents are facultative parasitic fungi, ubiquitous as saprophytes, humidity being the limiting factor for them to become parasites. Apart from the ear, Fusarium species can also attack other plant organs, especially the roots and wheat seedlings. Crop losses are reflected in flower sterility and poor grain filling. The formed grains have a low 1,000 grain mass, are scaly, and are carriers of the mycelium of the fungus, through which they can contribute to the transmission of infection. To combat this disease preventively, it is necessary to deep plow and bury the plant residues of the previous year, apply nitrogen and treat the seed and use fungicides.

Protein substances usually represent 10-16% of the grain mass (with limits between 8 and 24%) and are mostly located towards the peripheral parts of the grain (coats, aleurone layer) in the embryo and scutellum. Quantity and composition proteins give the nutritive quality of the grain. The accumulation of proteins in the grain depends on a number of factors, such as: the wheat species, the variety, the climatic conditions, the natural fertility of the soil and the doses of nitrogen fertilizers used.

Through the fertilization plan, for the wheat crop, for a production of 6,000 kg/ha, the dose of N200:P100:K80 was used. Fertilization with 40 N/ha of COMPLEX 15/15/15 in autumn has a greater effect on production than if 60 N/ha of COMPLEX 5/15/15 is applied in spring. In autumn, 150 kg/ha of COMPLEX 15/15/15+3S+Zn were applied to the analyzed company.

**Analysis of the qualitative parameters of the corn crop**

For the corn crop obtained within the company, we analyzed the following parameters: humidity, broken grains, foreign bodies, defective grains, weed seeds.

Foreign bodies exceed the value in 2021, while in 2022 it remains within the allowed limit. Defective grains do not exceed the STAS in any of the years, but weeds exceed the STAS value in 2022.

There can be several causes for the unfavourable indicators present, the corn crop being a sensitive one when there is a lack of water in the soil.

Table 2. Analysis of qualitative parameters of corn crop in the period 2021-2022

| Corn crop | | | |
|---|---|---|---|
| **Parameters** | **Year 2021 Value (%)** | **Year 2022 Value (%)** | **STAS** |
| Humidity | 17.2% | 12.8% | 17% |
| Broken grains | 2.2% | 3.5% | 2% |
| Foreign bodies | 1.2% | 1% | 1% |
| Damaged grains | 0.2% | 0.4% | 1% |
| Weeds | 0.5% | 1.5% | 1% |

Source: Quality documents of the company with an agricultural profile [9].

Corn culture is sensitive when it does not have enough water in the soil, which can lead to the above unfavourable parameters. Drought is one of the main enemies, because the lack of water in the soil in time does not favour the development of corn grains, as well as the lack of some substances from the soil, necessary for their development.

Corn is stored in silos, at a humidity lower than 14%. Marketers are generally looking for corn that has a moisture content of between 13 and 14% and a percentage of broken kernels of no more than 2%. In order for the corn to reach a humidity required by the market, in some cases special drying equipment is used. Also, in order to keep the corn in good condition in the warehouse, various phytosanitary products designed specifically for this purpose can be applied.

The seed from the corn crop, at the analyzed company, was treated with Royal ECO 42S and MAXIM XL 035 FS.

According to its productive potential, maize extracts from the soil, for 1000 kg of grains and related secondary production, 22-32 kg of N; 8-16 kg $P_2O_5$; 22-32 kg $K_2O$; 10-12 kg CaO and 4 kg MgO. It is a plant, therefore, with an important need for N and K, and it has been proven that among the microelements it is sensitive and effective first of all when applying zinc, but also boron.

**Analysis of qualitative parameters of barley culture**

According to the analysis reports, the barley culture registered the following values of the quality parameters (humidity, hectolitre mass, impurities, broken grains, damaged grains, germinated grains, foreign bodies):

Table 3. Analysis of qualitative parameters of barley crop in the period 2021-2022

| Barley crop | | | |
|---|---|---|---|
| **Parameters** | **Year 2021 Value (%)** | **Year 2022 Value (%)** | **STAS** |
| Humidity | 12.54% | 16.20% | 14% |
| Hectolitre mass | 66.62% | 54.60% | 60-62% |
| Impurities | 7.9% | 12.6% | 10-12% |
| Broken grains | 2% | 1.6% | 3-5% |
| Damaged grains | 16.1% | 6% | 8-12% |
| Germinated grains | 0 | 0 | 3-6% |
| Foreign bodies | 1.8% | 2% | 3-4% |

Source: Quality documents of the company with an agricultural profile [9].

The humidity for the barley crop, the best was recorded in 2021, when it had a value of 12.54% and did not exceed the STAS of 14, and the lowest value, which disadvantages the farmer, was recorded in 2022, when it had a value of 16.2%. Fees are charged for the difference from the normal value, for drying the barley.

From the point of view of the hectolitre mass, for the barley crop, the best value was in 2021 when a value above the minimum allowed limit was recorded, and the weakest was recorded in 2022, with a decrease of almost 10% from the normal value.

The impurities with the best value were also recorded in 2021, and the barley with the most impurities, which affects the entire production and causes losses from the total harvested, was in 2022.

Impurities can appear for several reasons: the lack of important substances from the soil and the appearance of weeds that retain moisture in the barley culture, foreign bodies and other foreign seeds, the inadequate herbicide, the lack of rain and the improper adjustment of the combine that harvests it - can cause losses as well as grain breaks.

Broken grains, sprouted grains, as well as foreign bodies did not exceed the limit in any of the years, while defective grains affected the production of 2021, when a value above the standard was recorded, which determines the inclusion of barley in the category of Grade 2 - a worse qualitative barley.

For 100 Kg of grains and related secondary production, barley consumes 2.4 – 2.9 kg of N; 1.1 – 1.3 kg $P_2O_5$ and 2.1 – 2.8 kg $K_2O$. In spring, the rate of absorption is intense, which determines that in the months of April - May (straw formation), the barley absorbs approx. 83% of nitrogen, 84% of phosphorus and 87% of potassium. The determination of the doses of fertilizers is done as with wheat, taking into account the level of the desired production and its destination (forage or malt), the fertility of the soil, the cultivated variety. The setting of nitrogen doses is done very carefully, avoiding the fall of the plants, which in barley causes very high harvest losses.

## CONCLUSIONS

In conclusion, following the analysis of the qualitative parameters recorded in the two years, we can say that the exceedances compared to STAS existed, but in a small percentage and only in some of the analyzed parameters.

The best wheat from the point of view of hectolitre mass, impurities, the protein it contains and gluten is the wheat from the year 2021. It presents the qualities of a superior wheat through its characteristics. In the other year, 2022, values were approximately equal, but not as good as those of the previous year.

For the corn crop, the year 2022 was much better than the year 2021, the quality indices of this year being included in the STAS.

For the barley crop, of the 2 analyzed years, the best crop was recorded in the agricultural year 2021, and the one in 2022 included barley in the grade 2 category. This year we found a contaminated barley, with many impurities of organic and inorganic nature, which affects the entire production and causes significant harvest losses.

In the future, I recommend the company's staff to carry out a more careful work of the soil, as well as weeding, timely fertilization of the crops, but also the use of quality products.

In order to carry out all the works on time, it is recommended to purchase new, more efficient machines and increase the area of land both owned and leased, as well as the practice of new crops, because its positioning is in the South-Eastern region of the Romanian Plain and we know very well that the soil is suitable for the diversification of crops, so it is a very big advantage in business optimization.

Regarding the quality of the seeds, it can be observed that the values fall within the STAS values and do not present a threat. Owning an analysis laboratory is a strong point for the object of activity, because they can very easily monitor the parameters of the quality indices.

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# THE AGRO-PRODUCTIVE EFFICIENCY OF SOME RAPESEED HYBRIDS IN THE PEDOCLIMATIC CONDITIONS IN THE GĂTAIA PLAIN, TIMIȘ COUNTY, ROMANIA

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***Abstract***

*Today, rapeseed ranks 5th among edible plant oil, with wide uses in industry and nutrition, as well as in medicine. The use of rapeseed is quite widespread: it is used in the manufacture of margarine, of paints and lakes, of soap, in the textile industry, in combination with sulfur, as well as unrefined oil used in the lubrication of the engines and as biofuel with traits like those of the diesel. Promoters of rapeseed cultivation claim that rapeseed oil is of high quality, for both cooking and salads, being the healthiest food oil. Research on rapeseed and its industrial uses are focused on four main directions: obtaining fuels (known under different names: green diesel, biodiesel, etc.) intended for use in diesel engines; obtaining industrial solvents – because the current solvents of mineral origin contain aggressive and toxic aromatic compounds for humans and animals; obtaining lubricants for industry and agriculture, including hydraulic oils; and obtaining specific fatty acids – especially erucic acid, component of antifoaming products from the detergents industry. Research conducted led to both theoretically and practically important results regarding this crop.*

***Key words*: *rapeseed, production, oil content***

## INTRODUCTION

Canadian specialists consider the current oil rapeseed a genetically - invented plant by breeders through conventional methods and, to distinguish it from the traditional rapeseed, they named it canola (Canadian Oil Law Erucic Acid). Colza rapeseed is one of the most important oil plants, being cultivated in Romania (in 2020) on an area of 342,600 ha [17]. Colza rape gives good results in the area of maize cultivation and winter cereals [12, 13, 19].

Currently, there is an increased demand for rapeseed for human nutrition, biodiesel, or fodder for animal feed. One should not forget that the biodiesel industry is constantly developing being, at the same time, one of the big rapeseed users [2, 9, 15]. In fact, this industry processes almost half of the rapeseed oil produced in Europe because it is a fuel more economical than diesel, biodegradable and limiting atmospheric pollution. Vegetable oils are used in the human body in a proportion of 94.5% being exceeded from this point of view only by cow butter [18].

Vegetable fats are used in numerous branches of the industry, but their main use is, directly or indirectly, in human nutrition. Colza seeds contain 19.6-23.8% protein substances [18].

By improving processes, using as a basis the LIHO and ORO varieties, they have reached an erucic acid content of 1-2% rapeseed oil, and then to varieties without erucic acid, type "0" (zero erucic) [18]. Claims that research on rapeseed and its industrial use focuses on four main directions:

1. Producing fuel (known under different names: green diesel, biodiesel, etc.) intended

for use in diesel engines. There are two ways to use this oil as a fuel:
- cold pressed rapeseed oil
- esterified rapeseed oil

2.Producing industrial solvents
3.Producing lubricants for industry and agriculture, including hydraulic oils
4.Producing specific fatty acids – especially erucic acid, component of antifoaming products for the detergent industry.

Food security will be challenged by the growth of the world's population, reaching over 9 Billion people in the next 50 years (United Nations, 2013). The "Green Revolution" improved the yield of energy-dense crops like cereals and oil species, allowing the increase in food calories, fats and proteins consumed by mankind [5, 7].

As a source of fats and proteins, one of the healthiest edible oils for human consumption [11, 8], it has globally increased seed production, reaching 73.8 million t in 2014 (Faostat, 2017) and partially powered by the rising demand for biofuels [16, 18].

The increase in rapeseed production only occurred when its use for human and animal consumption began. From the middle of the 19th century, its cultivation increased, and its oil was used primarily for industrial purposes and animal feed [17]. The growing interest of the industry (biodiesel) and the appearance of modern varieties and hybrids gave a big boost to its cultivation [1, 2, 3, 6, 4, 14].

## MATERIALS AND METHODS

The research that is the object of this study aims to test some rapeseed hybrids in order to introduce them in culture and to optimize some technological links in order to obtain superior economic and quality crops.

In this sense, for the introduction of new varieties and hybrids, comparative cultures have been organized in the territory of Gătaia.

The biological material under research was represented by five rapeseed hybrids belonging to different companies. The hybrids taken in the study were the following: UNBERTO, EXPANSION, EXCIDET, ARCHITECT, and PT245.

The research carried out in the experimental field regarding the identification of the particularities of some technology links, important for the rapeseed, specific to the study area targeted are as follows:
- Establishing the structure of varieties in the Gătaia area
- Researching the cultivation technology.

The experience was of the monofactorial type, being located on the territory of Gătaia.

The soil on which the experience was carried out is a typical preluvosol, clayey-dusty/ clayey-clayey on clay.

The climatic conditions recorded during the 2020-2021 period were favorable to the rapeseed culture, given the large productions obtained during this period.

The average temperature recorded between September 2019 and July 2020 was 11.65ºC, and between September 2020 and July 2021 it was 11.54ºC, values that did not influence the rapeseed culture. In contrast, the quantity of precipitation had different values, 516.20 mm between September 2019 and July 2020, and 553.70 mm between September 2020 and July 2021. The distribution was uneven, which influenced the production of rapeseed.

Results highlight the behavior of the five rapeseed hybrids in the pedoclimatic conditions of the Gătaia administrative territorial unit and attest their suitability and the productive potential of this crop in the current climatic context.

## RESULTS AND DISCUSSIONS

Results obtained in the experimental year 2020-2022 are presented in Table 1.

Table 1. Synthesis of harvest results in rapeseed hybrids in the experimental cycle 2020-2021

| Variant | Yield kg/ha | % | Difference kg/ha | Significance |
|---|---|---|---|---|
| EXPANSION DK | 3,350 | 105.34 | +170 | xxx |
| EXCIDET DK | 3,250 | 102.20 | +70 | xx |
| PT275 PIONEER | 3,250 | 102.20 | +70 | xx |
| **X – mean of the field** | **3,180** | **100.00** | **Mt.** | **-** |
| UMBERTO KWS | 3,100 | 97.48 | -80 | 000 |
| ARCHITECT LG | 2,950 | 92.76 | -230 | 000 |

DL 5%= 31 kg/ha; DL 1%= 47 kg/ha; DL 0.1%= 76 kg/ha.
Source: Own calculation.

The results point out that, under experimental conditions, within the limits of the factors studied with mean harvests between 3,350 kg/ha and 3,250 kg/ha, there were three hybrids: EXCEPTION with a mean harvest of 3,350 kg/ha, 5% higher than the mean of the field and with a harvest difference of 170 kg/ha statistically insured as very significant.

The hybrids EXCIDET and PT275 yielded 3,250 kg/ha, with a harvest difference of 70 kg/ha, 2% higher than the mean of the field, statistically insured.

The other two hybrids, ARCHITECT and UMBERTO yielded 2,950 kg/ha – ARCHITECT and 3,100 kg/ha – UMBERTO.

The results obtained in the researched territory, the comparative culture with five winter rapeseed hybrids from different companies lead to the conclusion that all can be cultivated in the reference area, but the testing of other varieties or hybrids with higher productive potential is required to better use the pedoclimatic potential of the area.

MMG is an element of productivity and depends on several factors.

The different values of the MMG in the two years are levelled after the average of the two experimental years, but the data cannot be studied as a feature of the hybrid.

MMG oscillates between 4.21 g (ARCHITECT LG) and 4.95 g (EXPANSION DK). Values of the MMG above the mean of the field were also achieved by the PT275 PIONEER hybrid, 4.81 g. The average of the 5 hybrids is 4.62 g (Table 2).

Table 2. Synthesis of MMG results in rapeseed hybrids in the experimental cycle 2020-2021

| Variant | MMG (g) | % | Difference (g) | Significance of the difference |
|---|---|---|---|---|
| EXPANSION DK | 4.95 | 107.14 | +0.33 | xxx |
| PT275 PIONEER | 4.81 | 104.11 | +0.19 | xx |
| **X – mean of the field** | **4.62** | **100.00** | **Mt.** | **-** |
| EXCIDET DK | 4.60 | 99.56 | -0.02 | - |
| UMBERTO KWS | 4.54 | 98.26 | -0.08 | - |
| ARCHITECT LG | 4.21 | 91.12 | -0.41 | 000 |

Dl 5% = 0.13 g; Dl 1% = 0.18 g, Dl 0.1%= 0.26 g.
Source: Own calculation.

Lower MMG values compared to the mean of the field: ARCHITECT LG, UMBERTO KWS and EXCIDET DK, between 4.21g and 4.60 g.

The MMG percentage compared to the mean of the field oscillates between 91.12% and 107.14%. The differences from the mean of the field are 0.19 g and 0.33 g, respectively (Table 2).

Due to its multiple uses, the rapeseed areas in our country have expanded. At the same time, new high-potential rapeseed hybrids have been introduced into culture, both in terms of production and percentage of oil.

The amount of oil extracted depends on both the production obtained and the cultivated hybrid.

The average of the 2 years regarding the amount of oil/ha does not help the farmer at the moment.

The amount of oil reached values between 1,190.92 l/ha (ARCHITECT LG) and 1,424.07 l/ha (EXPANSION DK). Productions above the mean of the field were also in the hybrids PT275 PIONEER (1,323.59 l/ha) and EXCIDET DK (1,331.74 l/ha). Depending on the average of the 5 hybrids, the extraction process reached values between 90.60% and 108.34%, respectively (Table 3 and Fig. 3).

The production bonuses are between 9.15 l/ha (PT275 PIONEER) and 109.63 l/ha (EXPANSION DK). The production increase of 109.63 l/ha is very significant (Table 3).

Table 3. Synthesis of results in rapeseed oil from rapeseed hybrids in the experimental cycle 2020-2021

| Variant | Oil (l/ha) | % | Difference (l/ha) | Significance of the difference |
|---|---|---|---|---|
| EXPANSION DK | 1,424.07 | 108.34 | +109.63 | xxx |
| EXCIDET DK | 1,331.74 | 101.31 | +17.30 | - |
| PT275 PIONEER | 1,323.59 | 100.69 | +9.15 | - |
| **x – mean of the field** | **1,314.44** | **100.00** | **Mt.** | **-** |
| UMBERTO KWS | 1,301.97 | 99.05 | -12.47 | - |
| ARCHITECT LG | 1,190.92 | 90.60 | -123.52 | 000 |

Dl 5% = 48.00 l/ha; Dl 1% = 67.38 l/ha; Dl 0.1%= 95.12 l/ha.
Source: Own calculation.

The average of the two years regarding the quantity of oil helps the farmer today.

To see whether the rapeseed culture at the present time is profitable, the authors chose to

carry out the main indicators of economic efficiency.
The indicators analyses are the following:
Main production (kg/ha)
Value of the main production (RON/ha)
Production expenses (RON/ha)
Production costs (RON/kg)
Total profit (RON/ha)
Profit rate (%).
For the indicator "Production expenses", the expenses quotation for each experimental variant was prepared. The average prices from the years 2020-2021 was used.
The average price of valorizations of 1 kg of rapeseed was 2.03 RON/kg.
The largest production of 3,350 kg/ha was obtained in the EXPANSION DK hybrid, and the lowest production was in the ARCHITECT LG hybrid – 2,950 kg/ha (Table 4).

Table 4. Main indicators of economic efficiency (2020-2021)

| Variant (hybrid) | Main yield kg/ ha | Value of main yield (RON/ ha) | Production expenses (RON/ ha) | Production costs (RON/ kg) | Total profit (RON/ ha) | Profit rate (%) |
|---|---|---|---|---|---|---|
| UMBERTO KWS | 3,100 | 6,293 | 3,205 | 1.03 | 3,088 | 96.34 |
| EXPANSION DK | 3,350 | 6,800 | 3,261 | 0.97 | 3,539 | 108.52 |
| EXCIDET DK | 3,250 | 6,598 | 3,332 | 1.02 | 3,266 | 98.01 |
| ARCHITECT LG | 2,950 | 5,987 | 3,239 | 1.09 | 2,748 | 84.84 |
| PT275 PIONEER | 3,250 | 6,598 | 3,282 | 1.00 | 3,316 | 101.03 |

Source: own calculus.

The value of the main production oscillated between 5,987 RON/ha in the ARCHITECT LG hybrid and 6,800 RON/ha in the EXPANSION DK hybrid (Fig. 1)
Production expenses were influenced by the value of the inputs. They oscillated between 3,205 RON/ha (UMBERTO KWS) and 3,332 RON/ha (EXCIDET DK) (Fig. 2).
Production costs in all hybrids was below the valorizations price (2.03 RON/kg). In the EXPANSION DK hybrid, the lowest production cost of 0.97 RON/kg was recorded, while in the ARCHITECT LG hybrid, the highest production cost was 1.09 RON/kg.

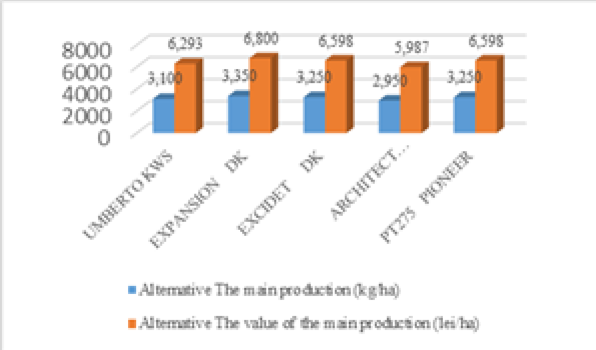


Fig. 1. The value of the economic indicators: main production (kg/ha) and the value of the main production (RON/ha) during the period 2020-2022
Source: Own calculation.

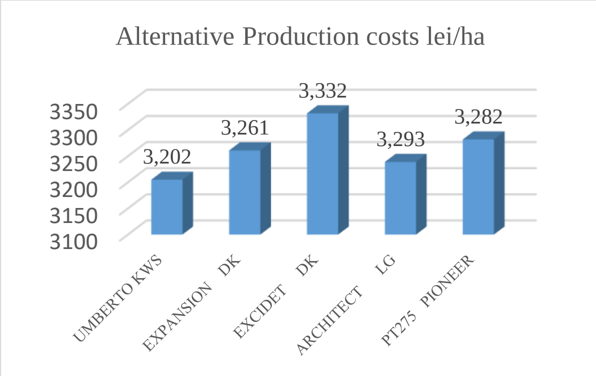


Fig. 2. Production expenses during the period 2020-2022
Source: Own calculation.

Total profit oscillated between 2,748 RON/ha and 3,539 RON/ha. Profit values cover the production expenses and allow the start of a new production cycle (Fig. 3).


Fig. 3. Value of economic indicators: the total profit (RON/ha) during the period 2020-2022
Source: Own calculation.

The profit rate oscillated between 84.84% (ARCHITECT LG) and 108.52% (EXPANSION DK). High values regarding the profit rate were achieved in all hybrids (Fig. 4).

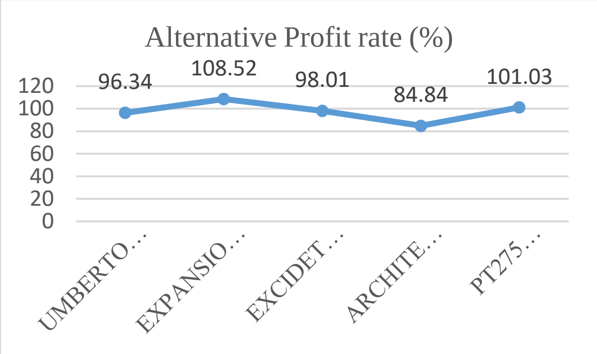


Fig. 4 The value of economic indicators: total profit rate (%).
Source: Own calculation.

The best results were obtained in the EXPANSION DK hybrid.

## CONCLUSIONS

Following the research carried out in the two experimental years (2020-2021), the following conclusions were detached.
The climatic conditions recorded during the 2020-2021 period were favorable to rapeseed culture, given the large productions obtained during this period.
Synthesis of results over the two years (2020 and 2021) indicates a mean of the field of 3,180 kg/ha. Production oscillated between 2,950 kg/ha (ARCHITECT) and 3,350 kg/ha (EXPENSION DK).
The value of the main production oscillated between 5,987 RON/ha in the ARCHITECT LG hybrid and 6,800 RON/ha in the EXPANSION DK hybrid.
Production expenses were influenced by the value of the inputs. They oscillated between 3,205 RON/ha (UMBERTO KWS) and 3,332 RON/ha (EXCIDET DK).
Production costs in all hybrids were below the valoriation price (2.03 RON/kg). In the EXPANSION DK hybrid, the lowest production cost of 0.97 RON/kg was recorded, while in the ARCHITECT LG hybrid, the highest production cost of 1.09 RON/kg was recorded.
Total profit oscillated between 2,748 RON/ha and 3,539 RON/ha. Profit values covered production expenses and allowed the start of a new production cycle.
Profit rate oscillated between 84.84% (ARCHITECT LG) and 108.52% (EXPANSION DK). High values of the profit rate were achieved in all hybrids.
Following the analysis of the 5 hybrids, the best results were obtained in the EXPANSION DK hybrid, with a production of 3,350 kg/ha and a value of 6,800 RON/ha, production expenses of 3,261 RON/ Ha, a production cost of 0.97 RON/kg and a profit rate 108.52%, determined by the highest profit (3,539 RON/ha).
Results obtained in the studied territory, the comparative culture with five autumn rapeseed hybrids from different companies lead to the conclusion that all can be cultivated in the reference area, but the testing of other varieties or hybrids with higher productive potential is required for a better use of the pedoclimatic potential of the area.
Based on the obtained results, the following recommendations have been issued:
- Analyzing the pedo-climatic conditions of the area
- Knowing all the requirements of the hybrids to be tested in the future in another area
- Choosing the range of hybrids to be tested in the area
- Complying with all technological steps
- Assessing production
- Processing experimental data statistically
- Choosing the hybrids that have best adapted to the area and that will be cultivated.

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# EFFECT OF INCOME DIVERSIFICATION STRATEGIES ON SMALLHOLDER CASSAVA FARMERS' HOUSEHOLD FOOD SECURITY IN SOUTHWEST, NIGERIA

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***Abstract***

*Food insecurity remains a challenge in the developing regions of the world and in particular among rural folks whose main source of livelihood is from farming and thus time bound. The study through primary data from 120 cassava farming households examined how income diversification strategies could improve food security. Descriptive statistics, USDA food security scale and logit regression model were employed for the analysis. 42.5% were food secure while 57.5% were food insecure. 'Cassava income + agricultural incomes' (CA); 'Cassava income + non-agricultural incomes' (CN) and 'Cassava income + both agricultural and non-agricultural incomes' (CAN) were the diversification strategies identified. Income diversification strategies and increased farm size exerted significant positive influence on household food security. Promoting income diversification into other agricultural enterprises (beyond cassava production) and non-agricultural businesses is therefore vital to enhancing household food security. Efforts to transform cassava farmers into large scale commercial producers will also enhance food security substantially.*

***Key words***: *agricultural income, livelihoods strategies, non-agricultural enterprises*

## INTRODUCTION

Attainment of security in terms of food in most developing regions across the globe including Nigeria remains a concern at the center stage. About 70% of the population in Nigeria are agrarian in nature as it serves as a means of livelihood for a significant number of people particularly rural inhabitants who produce food through their engagement in various agricultural-related activities in a bid to ensure food security [18].

According to [21], food security refers to a condition in existence "when everyone at all times has unhindered physical, economic and social access to enough, safe and nutritious food that meets their dietary and food needs so as to live an active and healthy life either at the individual, household, national, regional and global levels." Food insecurity on the other hand implies a condition when human beings experience some difficulties in accessing food both physically and economically [6]. Despite several programs and interventions over the years in Nigeria to attain food security, the situation still persists as over 8.7 million people in Nigeria are still food insecure [25]. In addition, a recent situation report on food insecurity in Nigeria revealed an increasing trend in the prevalence of the situation as the percentage rose from 6.6% in 2014 to 21.4% in 2020 [22]. Also, various indicators of food insecurity like calorie deficiency, global hunger index and food consumption score further showed that food insecurity is a major challenge in Nigeria as these indices were far from the standard threshold. For instance, the 2021 Global Hunger Index ratings showed that from the 116 countries considered, Nigeria was in the 103rd position. Also, the global hunger index score of 28.3 showed that the hunger level in the land is alarming [9].

Poverty, seasonal and geographical fluctuations in the prices of local food production experienced in Nigeria as a result of staggering weather conditions on agricultural activities, low infrastructures and global fluctuations in the price of staple foods that are imported have been identified out of several other factors as drivers food insecurity [24, 7].

Smallholder farmers as described by [8] refers to farmers whose productive potential spans from 0.1 to 4.99 hectares of land holdings. They are further characterized by subsistence production, restricted access to current and improved agricultural technologies and generally their scale of operations usually does not attract appreciable inputs, labour and capital investment.

[3] reported that over 80% of farmers that grow food items consumed in Nigerian households are smallholders and they constitute a major pillar in the Nigerian agricultural sector.

Smallholder farmers in Nigeria have limited access to credit facilities which reduces their productivity to a great extent and the likelihood of being food secured. They can run out of food materials especially during the post-harvest periods when income from farming activities dwindles and as such, they are economically and financially vulnerable. Non-involvement in other income-generating livelihood activities could impact negatively their welfare and hence the need for income diversification is salient. According to [11], income diversification refers to changing from one crop to a combination of food crops or even high-valued cash crops (crop diversification) or switching from agricultural-bound enterprises into non-agricultural-bound enterprises (non-farm diversification). Furthermore, income diversification among rural folks may be viewed as a dynamic adaptation process through which threats and opportunities are responded to among farmers and also the management of risk and the need to acquire extra income so as to secure their livelihoods and subsequently improve their living standards.

Due to the subsistence-oriented farming patterns in Nigerian agriculture, smallholder farmers are vulnerable to risk and poor market orientation. As Cassava crop is resilient to drought and offers many agribusiness opportunities, it is considered the strategic driver to attaining sustainable economic development, high income levels and reduce poverty [10].

In this context, income diversification implies a process of combining cassava farming with other income-generating activities (farming related or non-farming related) in other to improve their standard of living. In addition, smallholder farmers do not solely produce their households' food needs and other items, they also buy some needed food and non-food materials from the market especially during the off-season when prices of food items are at the peak. Focusing on cassava farmers is due to the peculiar characteristics of the crops in combating poverty in Nigeria as documented by [4] and [16].

The study will add to the existing literature on how income diversification could influence food security particularly among smallholder farmers. Objectives specifically measured are to describe the socio-economic characteristics of the respondents; determine the food security status of cassava farmers' households and examine the effect of income diversification on food security of the household.

## MATERIALS AND METHODS

***Area of Study***

Smallholder farmers that were into cassava production in Odeda Local Government of Ogun State were the respondents for the study. Odeda is situated in the North-Central region of the state with boundaries with Abeokuta South, Obafemi-Owode and Abeokuta North local government areas in the South, East and West respectively. It is also bounded in the North by Oyo state. It is a tropical rainforest vegetation zone notably with rainfall for an average of seven months. The mean temperature is about 32°C and relative humidity of about 95% [19]. It has a land area of 1,320 $km^2$ and an estimated population of 152,300 [13]. Farming is the major occupation of the inhabitants with specialization in crop production and few engagements in livestock farming.

***Sampling procedure***

Multistage sampling procedure was employed in selecting the cassava farmers interviewed.

In stage one purposive selection of five regions out of the 10 regions notably known for cassava cultivation was done. In stage two, random selection of four villages from each region was done to give a total of twenty villages. In the last stage, proportionate sampling to size was done from where data were collected from 120 cassava farmers through the use of a well-structured questionnaire.

***Analytical technique***

Descriptive statistics (frequencies, percentages and mean) and inferential statistics were used for the analysis. Socio-economic characteristics of farmers, classification of cassava farming households according to their food security status as well as choice of income diversification strategy were summarized using descriptive statistics. Food security status was estimated using the USDA approach and logit regression was employed to examine the effect of income diversification on food security.

***Description of income diversification strategy by cassava farmers***

The four categories of income diversification strategy are as follows.

**(i)Cassava farm income only (C Strategy):** These are group of farming households that depend only on income from cassava farming. They do not grow other crop alongside cassava nor get involved in other income generating activities other than cassava farming. Simply put, this group did not diversify their income source.

**(ii)Cassava farm income and other agricultural sources (CA Strategy):** Farmers in this category involve themselves in other income generating activities that is agriculture-related alongside cassava farming. Such agricultural activity could be growing other crops, livestock farming, fish farming, earning income (wage) from other commercial or private farms.

**(iii)Cassava farm income and other non-agricultural sources (CN Strategy):** These farmers in addition to their cassava farming involved themselves in other income generating enterprises that is not relate to agriculture such as non-agricultural self-employment of any sort, managing a shop, trading and income earned from artisan related activities.

**(iv)Cassava farm, agricultural and non-agricultural income sources (CAN Strategy):** Cassava farmers in this group earn incomes simultaneously from all the mentioned sources above. They engage in both agricultural and non-agricultural related activities.

***Estimation of cassava farmers' household food security status***

From literature, it is an established fact that income and economic access to food are directly proportional to one another. Considering the above, the study focused on the access component of food security since the study is on income diversification. Food security status of cassava farming households was examined by employing the USDA (United States Department of Agriculture) Food Security Approach. Households are classified into four classes in line with their food security status which was generated from the USDA survey tool [15]. Data were collected by employing an 18-item household food security questionnaire. Determination of household food security status was derived following the respondents' responses (yes/no) to a list of questions regarding their actions when there are difficulties in meeting the food needs of the household members [5]. Each of the question inquires if the action took place at any time in the household during the last one month [10] and was due to lack of money or food but not voluntary fasting or dieting. The total number of positive responses (yes) received from the list of questions in each household was used to generate a score. In households with children, the score ranges from 0 to 18 and 0 to 10 in households without children. A major assumption in this measurement model is that households with greater food insecurity score demonstrate a higher likelihood of a "yes" response to each of the asked questions while more food secured households will demonstrate a higher likelihood in responding negatively to each of the asked questions. The probability of a positive response to each of the questions asked is statistically independent for all households with similar level of food insecurity. In line with this, the households were grouped into four classes, namely food secure (FS), food insecure without hunger (FIWH), food insecure with moderate hunger (FIWMH) and food insecure with severe hunger (FIWSH).

Table 1. Food security category according to USDA

| Food security status | Household with children (18 questions) |
|---|---|
| Food secure (FS) | Between 0 and 2 positive answers |
| Food insecure without hunger (FIWH) | Between 3 and 7 positive answers |
| Food insecure with moderate hunger (FIWMH) | Between 8 and 12 positive answers |
| Food insecure with severe hunger (FIWSH) | Between 13 and 18 positive answers |

Source: United States Department of Agriculture (USDA), 2016 [24].

**(i)Food secure households**: These households consistently access food without any problem, barriers or anxiety. These groups were allotted the value of 1 on the food security scale.

**(ii)Food insecure without hunger:** Accessing adequate food in these households may be challenging at times, but the quality, quantity and variety of their food consumption did not decreased. Adjustments is shown in their daily food management. These were assigned the value of 2 on the food security scale.

**(iii)Food insecure with moderate hunger:** Food intake quantity and normal eating patterns were not considerably disrupted among these groups of households but diet quality, variety and desirability are considerably disrupted. These were allotted the value of 3 on the food security scale.

**(iv)Food insecure with severe hunger**: For this group, there are reduction in food intake owing to financial constraints and as a result, eating patterns of few household members will be disrupted. They were assigned a value of 4.

***Estimating the effect of cassava farmers' income diversification on household food security***

Logit regression was employed to examine the effect of income diversification and other factors associated with a household's likelihood of being food secured. The dependent variable is dichotomous in nature because it is a binary choice model. The estimated probabilities lie between the range of 0 and 1 in the logit regression model. Also, they do not exhibit linear relationship with the explanatory (independent variables) but rather depend on the cumulative logistic distribution function expressed as:

$P_i$ = Prob{Y = 1/X} = $1/1+e^{-z}$ .........(1)

For easy interpretation,

$z_i = \alpha + \beta_1 x_1 + \beta_2 x_2 \ldots \beta_n x_n$. ..................................................................(2)

Equation 2 can be stated in its odd ratio form as:

The log of odds ratio or the logit =

$\mathrm{Ln}\left(\frac{Pi}{1-Pi}\right) = \alpha + \beta_1 x_1 + \beta_2 x_2 \ldots \beta_n x_n$.............(3)

where:

Pi = Probability of being food-secured.

$\beta_i$ = parameters of the independent variables,

i = indexes of the households observations.

To get the value of $z_i$, the probability of observing the sample among the respondents must be formed through the introduction of a dichotomous dependent variable $Y_i$ such that Y is equal to 1 if the household is food secure and 0 if otherwise. The model was estimated using the maximum likelihood estimation (MLE) technique. The explicit form of the model is expressed as:

Y = Household food security status (food secure = 1; 0 otherwise)

$X_1$ = Age of cassava farmer (years)

$X_2$ =Sex of cassava farmer (male =1; 0 otherwise)

$X_3$ = Household size (number of individuals)

$X_4$ = Cassava farm size in hectares (ha)

$X_5$ = Cassava yield (kg/ha)

$X_6$ = Income saved (naira)

$X_7$ = Cassava farm and other agricultural income sources, CA (CA= 1, otherwise 0)

$X_8$ = Cassava farm and other non-agricultural income sources, CN (CN= 1, otherwise 0)
$X_9$ = Cassava farm, other agricultural and non-agricultural income sources, CAN (CAN= 1, otherwise 0)
Note that households that fell into groups 1 and 2 above were collapsed into one and were regarded as food secure households while those that fell into the third and fourth were also merged into one group and were regarded as food insecure households**.**
The *A priori* expectations are for the variables to be positively related to food security except for age and household size which may be otherwise.

## RESULTS AND DISCUSSIONS

### Socio-economic characteristics of smallholder cassava farmers

The socio-economic characteristics of the cassava farming households are displayed on Table 2. Majority (96.7%) of the cassava farmers were male whereas just few (3.3%) were female. This means that men are more involved in agriculture and specifically, cassava farming possibly as a result of the arduous nature of the work as female will be underprivileged in this regard. Most (43.3%) of the cassava farmers were 50 years old and above, 23.3% were in the 30-39 age group. 20.8% fell into 40-49 age group while those less than 30 years of age constituted the least (12.5%). An average cassava farmer in the study area was 46.03 years. This suggests that majority of the farmers in the study area are still in their productive and active capacity, thus, could still actively engage in diverse income generating enterprises. This may possibly increase their chances of being food secured. Distribution of the respondents by marital status indicated that 13.3% were single and majority (86.7%) were married.

Table 2. Socio-economic characteristics of Cassava farmers

| Personal characteristics | Frequency | Percentage | Mean |
|---|---|---|---|
| ***Sex*** | | | |
| Male | 116 | 96.7 | |
| Female | 3 | 3.3 | |
| ***Age (years)*** | | | |
| <30 | 15 | 12.5 | |
| 30-39 | 28 | 23.3 | |
| 40-49 | 25 | 20.8 | |
| 50 and above | 52 | 43.3 | 46.03 |
| ***Marital Status*** | | | |
| Single | 16 | 13.3 | |
| Married | 104 | 86.7 | |
| ***Level of Education*** | | | |
| Primary | 60 | 50.0 | |
| Secondary | 56 | 46.7 | |
| Tertiary | 4 | 3.3 | |
| ***Household Size*** | | | |
| 1-4 | 87 | 72.5 | |
| 5-8 | 29 | 24.2 | |
| 9-12 | 4 | 3.3 | 4 |
| ***Farm Size (hectares)*** | | | |
| 1-4 | 99 | 82.5 | |
| 4.1 and above | 21 | 17.5 | 2.8 |
| ***Cassava Yield (kg/ha)*** | | | |
| 1,000-5,000 | 90 | 75.0 | |
| 5,001-10,000 | 9 | 7.5 | |
| 10,001 and above | 21 | 17.5 | 6,358.33 |

Source: Computed from Field Survey, 2021.

Furthermore, in terms of education, half (50.0%) of the farmers had primary school education, 46.7% had secondary education while very few (3.3%) had tertiary education level. Educational attainment could determine the level of opportunities available to improve income diversification strategies, improve food security and consequently reduce poverty level among the farmers. Majority (72.5%) of the sampled households had between 1- 4 persons in their households with very few (3.3%) had large household size of between 9 – 12 individuals in their households. 24.2% had between 5 – 8 individuals in their households. This distribution may not necessarily put pressure on household resources particularly food.

Majority (82.5%) of the farmers were small holder farmers who cultivate between 1-4 hectares of farmland while very few (17.5%) cultivate above 4 hectares of farmland. The mean farm size was 2.8 hectares. This suggested that the farmers are smallholder farmers. Yield from cassava showed that majority (75%) had between 1,000 and 5,000kg/ha, 7.5% had between 5,001 and 10,000kg/ha while just very few (17.5%) had yield above 10,000kg/ha.

**Income diversification strategies among the cassava farmers**

Distribution of cassava farmers according to diversification strategy employed is shown on Table 3. Cassava income in addition with agricultural income (CA) constituted the modal group. They represented 54.2% of the farmers interviewed. Furthermore, one-quarter (25.0%) of the cassava farmers (C) do not diversify at all and as such they rely only on income from cassava farming. Very few (12.5%) of the cassava farmers embrace income from non-agricultural sources in addition to income from cassava farming (CN). The least represented category (8.3%) are cassava farmers that combine income sources from both agricultural and non-agricultural related activities (CAN). This low representation might be due to the tedious and strenuous nature of involving in several income generating activities almost at the same time despite the fact that it was highly rewarding financially as found out in the study.

**Cassava income only (C strategy):** Farmers in this category earned a mean income of ₦ 71,500 and the standard deviation was 21381.19 (Table 3). The incomes earned in this category ranged from a minimum of ₦ 40,000 to a maximum of ₦ 95,000.

**Cassava income plus other agricultural income strategy (CA strategy):** More than half of the cassava farmers (54.2%) who practiced the ‘CA strategy’ earned between ₦ 68,000 and ₦ 191,000 during the growing season. The mean income for this category was ₦126, 556.14 with a standard deviation of 35102.85.

**Cassava income plus non-agricultural income strategy (CN strategy):** Their mean income was ₦ 143,880 and the standard deviation was GHS 21486.08. The least earner in this strategy earned ₦ 115,000 for the season while the highest income realized was ₦189, 000.

**Cassava income plus other agricultural plus non-agricultural income strategy (CAN):** The mean seasonal income of farmers who employed the CAN strategy was ₦ 185,320. The least income realized for the season was ₦ 155,000 while the highest earner had ₦225,000 as income.

Table 3. Income diversification strategies and mean income earned in Naira

| Income Strategies | Responses | | Mean Income (Naira) | | | |
|---|---|---|---|---|---|---|
| | Freq | % | Mean | Std. Dev. | Min. | Max. |
| Cassava income only (C) | 30 | 25.0 | 71,500.00 | 21381.99 | 40,000 | 95,000 |
| Cassava and other agricultural income (CA) | 65 | 54.2 | 126,556.14 | 35102.85 | 68,000 | 191,000 |
| Cassava and non-agricultural income (CN) | 15 | 12.5 | 143,880.00 | 21486.08 | 115,000 | 189,000 |
| Cassava and agricultural and non-agricultural income (CAN) | 10 | 8.3 | 185,320.00 | 22318.19 | 155,000 | 225,000 |

Source: Computed from Field Survey, 2021.

**Estimation of food security status of cassava farming households**

The food security status of the cassava farming households in the study area on Table

3 showed that 42.5% of the households are food secure, 6.7% are FIWH, 13.3% are FIWMH and 37.5% of the households are FIWSH. This implies that a large number (57.5%) of the households remain food insecure at different food insecurity levels. This implies that the problem of food insecurity exist among farming households particularly those in rural areas. This result agrees with earlier submission of [1] and [17] who reported that food insecurity situation is more pronounced among rural farming households than urban households.

Table 4. Food security status of cassava farming households

| Food security status | Frequency | Percentage |
|---|---|---|
| Food secured (FS) | 51 | 42.5 |
| Food insecure without hunger (FIWH) | 8 | 6.7 |
| Food insecure with moderate hunger (FIWMH) | 16 | 13.3 |
| Food insecure with severe hunger (FIWSH) | 45 | 37.5 |
| Food secure households | 59 | 49.2 |
| Food insecure households | 61 | 50.8 |
| Total | 120 | 100.0 |

Source: Computed from Field Survey, 2021.

**Effect of income diversification on food security among smallholder cassava farming households**

Examining the relationship between income diversification strategies and household food security among the cassava farmers, three categories of the farmers diversifying their incomes as obtained from the study was employed. They include those engaged in the agricultural enterprises (CA strategy), non-agricultural enterprises (CN) and those that combine both the agricultural and non-agricultural enterprises (CAN). The logit regression model showed that age and household size were significant but had a negative relationship with the likelihood of an household being food secure while cassava farm size and every of the income diversification strategies adopted by the farmers had a positive influence on household food security (Table 5). The result showed that engaging in any of income diversification strategies increases the likelihood of the households being food secure as positive relationship between each of the income diversification strategies was observed. Specifically, combination of cassava farming income with other agricultural sources will increase the likelihood of the household being secured by 9.6%. Furthermore adoption of additional income source from non-agricultural related activities will increase household food security by 7.3%. This findings is in tandem to the earlier reports of [12], [19] and [2] that participating in non-farm work is essential in raising income levels among farmers and it has the capability of improving household food security. The last category of income diversification strategy (CAN) is positive and statistically significant at 1%. This positive relationship will increase the likelihood of household being food secured by 17.8%. It can be deduced from the study that engaging in income diversification not only increase income levels among farmers but can also be viewed as a means of reducing various risks associated with farming activities, so by combining cassava farming with other agricultural and non-agricultural enterprise can help guarantee smooth and steady income flows among farmers particularly during the off season and this will consequently improve food security situation among the farming households.

Age of the farmer showed that an increase in the age of the farmer by one year will reduce the likelihood of household food security by 94.8%. This conforms to the earlier result of [14]. This may be due to the fact that the strength and energy to engage in other income generating activities reduces as the farmers grow older there by leading to lower income and thus making them susceptible to being food insecure.

Household size was negatively associated with the likelihood of household being food secure. This means that any additional increment in the present number of household members without appropriate increase in income may likely reduce the household purchasing powers, put additional pressure on household food resources and may impact negatively on household food security. As seen in this study, an increase by one person in the household will increase the likelihood of household food insecurity by 103%. This however agrees with the findings of [23].

Cassava farm size exhibited a positive relationship with the likelihood of household food security as expected. This implies that farmers that cultivate larger farm size will have more output and can be sold to get more income. This will ultimately increase the farmers' food purchasing capability and thus improve household food security. Specifically, an increase by one unit in the cassava farm size cultivated will increase the likelihood of food security among cassava farming households by 46% in the study area. This corroborates the earlier findings of [12] and [2] who maintained that an increase in the area of land under cultivation promote food security.

Table 5. Logistic regression result of the effect of income diversification on household food security

| **Variables** | **Estimated ß values** | **Standard error** | **z-value** | **p>\|z\|** |
|---|---|---|---|---|
| Age | -0.948*** | 0.210 | 4.514 | 0.000 |
| Sex | 0.230 | 0.588 | 0.391 | 0.746 |
| Household size | -1.030*** | 0.175 | 5.886 | 0.000 |
| Cassava farm size | 0.460** | 0.197 | 2.335 | 0.003 |
| Cassava yield | 0.409 | 0.789 | 0.518 | 0.682 |
| Income saved | 0.001 | 0.073 | 0.014 | 0.994 |
| Cassava and agric (CA) | 0.096*** | 0.022 | 4.364 | 0.000 |
| Cassava and non-agric (CN) | 0.073*** | 0.017 | 4.294 | 0.000 |
| Cassava, agric and non-agric (CAN) | 0.178*** | 0.051 | 3.490 | 0.000 |
| Constant | 7.245 | 2.717 | 2.667 | 0.000 |
| Log-likelihood function | -52.880 | | | |
| $\chi^2$ of Likelihood Ratio test (df = 9) | 41.36 | | | |
| Pro>chi$^2$ | 0.000 | | | |
| Number of observation | 120 | | | |
| Pseudo $R^2$ | 0.536 | | | |

Source: Computed from Field Survey, 2021.

$^{***}, ^{**}, ^{*}$ *implies Significance at p<0.01, p<0.05 and p< 0.10 levels respectively.*

## CONCLUSIONS

Nearly all of the cassava farmers engaged in income diversification but involvement in agricultural related enterprise constituted the modal group (CA). Income level increases with diversification as farmers that do not diversify at all earn the least income during the growing season.

Food security condition revealed that only 42.5% were food secure while 6.7%, 13.3% and 37.5% were FIWH, FIWMH and FIWSH respectively.

Achieving high food security scenario in the study area is positively associated with increasing the current farm size under cultivation and diversifying into agricultural and non-agricultural enterprises.

Awareness creation on the need for diversification among farmers in the study area would be helpful in improving food security conditions.

Also, technical advice and guidance should be provided to the farmers regarding the combination of enterprises so as to achieve the ultimate aim of improving food security.

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# SOCIO-ECONOMIC DETERMINANTS OF CLIMATE VARIABILITY ADAPTATION STRATEGIES AMONG FARMERS IN AKOKO SOUTHWEST LOCAL GOVERNMENT OF ONDO STATE, NIGERIA

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***Abstract***

*This study looked at socio-economic factors that affect how farmers of arable crops adapt to climate variability. Using a multistage sample strategy, a structured interview was conducted to gather information from 150 farmers in rural communities across the local governments in the study area. Descriptive and inferential statistics, including chi-square and Pearson Product Moment Correlation, were utilized to analyse the study's data. The research showed that farmers' socio-economic characteristics influence adaptation strategies. Household size ($\chi2=179.3$), and farm size ($\chi2=136.4$) positively influence adaptation strategies to be adopted by farmers at $p<0.05$. Additionally, there was a strong correlation between farmers' perceptions of climate variability and adaptation strategies ($r=0.591$, $p<0.05$). According to the study's findings, farmers' perceptions of climate unpredictability and socio-economic characteristics have a significant impact on their adaptation strategies. The study recommended that climate variability awareness and sensitization should be put in place at the Local, State, and Federal government level to have a community whereby the farmers are adeptly aware of the causes and effects of climate variability in the area.*

***Key words***: *adaptation, climate variability, farmers, socio-economic*

## INTRODUCTION

Agriculture is a key activity of human beings since it provides humanity with food, raw materials, shelter, clothing, fibre, and other by-products [26]. Hence, the importance of its interaction with the environment cannot be over-emphasized as the climate is the primary source of agricultural productivity. Because of this, the potential outcomes of variation in climate on agricultural production have generated a lot of reaction from different stakeholders in agricultural sector most especially the government and the farmers in particular [42]. Smallholders experience anxiety in different ways due to climate variability-related issue in the areas of longer and shorter period of rainfall, average temperature, and exposure to extreme climate variability which had significantly resulted to soil erosion during growing season and changes in sea level [38]. Given that agricultural production remains the majority of rural communities' primary source of food and income, climate variability conditions such as rising temperatures, decreased rainfall, and increased rainfall variability pose a serious threat to food security, crop yield, and the fight against poverty [19]. To maintain and enhance farmers' livelihoods and assure food security, it is crucial to adapt the agricultural industry to the negative consequences of climatic variability [11].

Beyond specific weather events, climate variability is the variance in the average condition and perhaps other data of the climate on all spatial and temporal scales [43]. The term "climate variability" is often used to denote deviations in climatic statistics over a given period (e.g. month, season, or year) when compared to long-term statistics for the same calendar period and these deviations, which are commonly referred to as anomalies, can be measured. They may be caused by the climate system's natural internal processes (internal variability or changes in natural or manmade external influences) (external variability) [37, 39].

Climate variability has become a global concern since it can adversely affect elements of various systems and sectors that threaten human wellbeing [41]. The Intergovernmental Panel on Climate Change's fifth assessment report provided clear evidence of variations in climate due to human activities [22]. Recently, climate variability has had obvious impacts on agriculture in many areas of Nigeria, particularly in Ondo State including Akoko Southwest. In order to create adaptation methods to deal with the challenges and risks of climate variability in the agricultural sector, farmers' understanding of climate variability is essential [7]. Such knowledge is essential in Nigeria since the key predictor of how effectively agriculture can be carried out is climate, and changes in climate have significant effects not only on the agricultural sector but also on other sectors [28]. Studies have revealed that the agricultural industry, food security, community health, natural resources, biodiversity, and water supply are all greatly threatened by climate variability and extreme weather events [14, 31]. The implications of climate variability would be stronger on socio-economic development and agriculture, which play considerably more significant roles in food production in Africa, according to projections from the intergovernmental panels on climate change [22].

Long-term adaptive actions have been outlined in Nigeria's national statements to the United Nations Framework Convention on Climate Change, along with several other African nations. In their National Adaptation Programme of Actions (NAPAs), which emphasize agriculture, food security, and water resource management, several of these nations have specified emergency adaptation measures [11]. Several of the strategies are yet to be effectively integrated, keeping many farmers in the dark about the difficulties that climatic unpredictability presents for agricultural productivity [44]. This indicates that because of their abilities to adapt to climate change or fluctuation, African nations are more likely to be more seriously affected. However, it is clear from the literature that farmers' awareness of socio-economic factors and adaptability to climate action are crucial to ensuring food security and safeguarding the lives of the poor [3].

Culture, traditions, market, water supply, climate, soil condition, plot size, and distance from home all influence what and how much is produced in agriculture [4]. Given the aforementioned, it is clear that one of the key elements affecting crop yield and production is the climate. Realizing that agricultural yield and production are crucial to the economics and way of life of Nigerian farmers, the fluctuation of rainfall, temperature, and humidity levels has been a pressing concern in a sustainable environment [36]. For example, a substantial portion of the rural dwellers relied on rain for agricultural activities, therefore farmers keep deeper relationships with nature and their natural resources serve as the foundation from which their fundamental needs are obtained [5].

Since the current climate change is anticipated to present increased risk, new combinations of risks, and potentially serious consequences, climate variability adaptation methods are those strategies that enable the individual or the community to cope with or adjust to the ongoing series of adaptations in response to climate variability [6]. As a result, policy options for reducing the negative impact of climatic variability on farm productivity have been identified, including adaptation [21]. When it comes to agriculture, adaptation enables farmers to meet their goals for securing their food, income, and livelihood despite deteriorating socio-economic and climatic situations like floods and droughts [32]. According to farm-level study, when adaptation is completely adopted, there might be a significant decrease in the negative effects of climatic variability [27]. Farmers may modify their agricultural output by using effective environmental resource management techniques include planting early-maturing crops, mulching, small-scale irrigation, choosing hardy types of crops, planting trees, and staking to prevent heat burns [20]. Additionally, [30] noted that knowledge gaps on suitable adaptation were among the impediments to adaptation options such as poor deployment of socio-economic attributes, poor access to the market and the labour crunch in agriculture. Therefore, it can be claimed that a lack of these variables as well as the ability to choose effective adaptive methods presents a significant barrier to agricultural output. The main factors of adaptation are information, awareness, labour, and capital.

However, climate variability uncertainty has been found to be a deterrent to investment in agricultural technology and market prospects [9]. Climate variability is a developing issue that poses a danger to peasant farmers, sustainable economic growth, and the entirety of human life [1].

In light of this, a research was conducted in the Akoko southwest local government area of Ondo State, Nigeria, to look at farmers' socio-economic drivers of climatic variability adaptation techniques. The study objectives are to:

(i) describe the socio-economic characteristics of arable crop farmers in the study area.

(ii) ascertain farmers' perception of climate variability on crop production.

(iii) determine socio-economic factors that influence farmers' adaptation strategies.

**Hypotheses**

(i)There is no significant relationship between socio-economic characteristics and farmers' adaptation strategies

(ii)There is no significant relationship between farmers' perception of climate variability and the adaptation strategies adopted by the farmers.

## MATERIALS AND METHODS

### Area of study

The study was carried out in Akoko South West Local Government Area of Ondo State, Nigeria. Akoko Southwest was created in 1996 (Ondo State Bureau of Statistics) with nine (9) communities and its headquarters area in the town of Oka Akoko. With a total population of 228,383 people and a land area of 340.1 (km) square, it is located in the deciduous rainforest of South Western Nigeria [33]. The local government is bounded to the north by Akoko north-east local government area, to the south by Ose and Owo local government area, and to the west by Ekiti state. The climate of the study area is equatorial with two peaks of rainfall. The first peak comes up between April and July while the second peak falls between late August and October. These two peaks are marked by heavy rainfall with a mean annual rainfall of 1,500mm-2,000mm. It has a relative humidity of 75-95% which results in severe cold conditions with a mean annual temperature of 23˚C-26˚C [35]. The study area lies between the latitude 7.23' 51.6˚ North and longitude 5˚41'40.7˚ East. This shows that the state lies in the rainforest and guinea savannah vegetation which is characterised by different plants and trees with a height of 5m and even more. The major form of occupation in the study area is agriculture, which is mainly of smallholder with the production of crops such as maize, yam, cassava, cocoa, cashew, rice, oil palm, timber, citrus, plantain, soya beans, cowpea, kola nut, and vegetables. More than 75% of the State's population benefits from it in the form of jobs and money. Additionally, it accounts for more than 70% of the state's GDP [40].

**Study population**

Farmers of arable crops in Akoko Southwest local government area of Ondo State make up the study's population.

**Sampling procedure and sample size**

The entire number of respondents for the survey was chosen using multi-stage sampling approaches. Five (5) communities from Akoko Southwest, namely Oke-Oka Akoko, Akungba-Akoko, Supare Akoko, Ikun Akoko, and Oba Akoko, were purposefully chosen for the initial stage. A simple random selection of two (2) wards from each community was used in the second stage. In the last phase, 15 farmers were randomly chosen from each of the chosen wards who are into arable crop farming, giving a total of one hundred and fifty (150) respondents.

**Data collection and analysis**

Data collection was carried out using primary and secondary sources. The primary data was collected using a questionnaire with well constructed open-ended and closed-ended questions, supported by the interview schedule while the secondary data were gathered from the literature that was available.

15 selected arable crop farmers from each of the wards chosen based on the list compiled by the Extension Agents of the Agricultural Development Programme (ADP) in the study region received the questionnaire. The data were examined using descriptive and inferential statistics including Chi-Square, Correlation analysis, and Ordinary least square regression to evaluate the proposed hypotheses. Frequency counts, percentages, and means were used to describe the respondents' socio-economic characteristics. Information on the respondents' methods for adapting to climatic fluctuation was gathered using a five-point Likert scale. The regression function postulated to isolate factors influencing adaptation strategies in the study was implicitly represented by the equation:

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, {}_e)$ ....................................................(1)

where:
Y = Adaptation Strategies
$X_1$ = Sex
$X_2$ = Age
$X_3$ = Farm Size
$X_4$ = Level of education
$X_5$ = Extension agent visit
$X_6$ = Experience in farming
$X_7$ = Perception
$X_8$ = Income of farmers
$X_9$ = Other sources of income
$X_{10}$ =Lack of credit
The functional forms are as follows:

$Y_1 = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \mu_i$ ...........................................................(2)

where:
a's and b's were parameters estimated while e represents the error term associated with data collected from the arable crop farmers. The error term was assumed to be normally distributed with zero mean value and constant variance. This regression analysis's main goal is to identify the variables that affect adaptation strategies.
Using inferential statistics like the Chi-square test and Pearson product-moment correlation analysis, the study hypothesis was put to the test.

## RESULTS AND DISCUSSIONS

### Socio-economic characteristics of respondents

According to Table 1, the average age of respondents in the study area is 48 years, with nearly half (42.0%) falling between the ages of 46 and 65 and 39.3% falling between the ages of 25 and 45. Only 16.0% and 2.7% respectively, of them were 66 to 95 years old. This means that adaptation to climatic fluctuation declines with age. That is, younger agricultural households are more likely to adapt to climate variability more than the elderly farming household. This is in line with the findings of [29], which observed that elderly people's physical strength, stamina, and mobility are reduced owing to their age, which then leads to them being unable to adapt to climate variability. More than half (62.7%) of the farmers were male while only 37.3% of them were female. This result indicates a higher percentage of males compared to females, reflecting the fact that the study area has a more male-dominated labour force in terms of crop production than the female. Although, the higher percentage of male to female farmers is insignificant to climate variability as the gender-based perceptions of climate variability will have weight on both male and female farmers' but women's capacity to adapt to climate variability risk is also lower than men due to lack of access to financial services, limited economic opportunities, and limited voice in decision making–especially in rural areas – where only 18 percent of adult women earn an income thereby affecting their decisions to implement adaptation practices to the threat of variations in climate [24]. A good number of the respondents as shown in Table 1 have large families of 4-7 (62.0%) with a mean household size of 5.1. This may be an advantage if they are used as farm labour. This is in line with [1, 10] who said that using households with larger sizes provides cheap labour to the households, increases their farm size, increases agricultural production, and enables the adoption of some practices which can mitigate the impacts of climate variability compared to households with smaller family size.

Table 1 further shows the average income of farmers, within a farming season was ₦101,000 ($242.9) with half (50.0%) of them earning above ₦81,000 ($194.8) per farming season. This suggests that farmers' use of adaptation methods, interest in alternative adaptation strategies, and willingness to pay for access to such adaptation strategies are all strongly influenced by their income levels. In addition, the study found that the average year of farmers' experience was 25.5 years. More than half (60.0%) of them had from 1-10 years and 21-30 years of farming experience respectively. This indicates that the likelihood of diversifying portfolios (that is, adopting new crops or crop varieties, or using mixed farming systems), changing planting dates, and changing the amount of land under production increases with farm experience. This finding is in line with that of [11], who found that farmer attitudes, amount of farming experience, and income all influence how well farmers adjust to climatic unpredictability. Additionally, 14.7% of farmers have no formal education, compared to 22.0% of farmers with a primary education and 38.7% of farmers with a secondary education. While only 24.6% of respondents had a bachelor's degree or less, this indicates a respectable level of literacy in western education, as seen in Table 1. Because educated individuals are better able to access information, they play a crucial role in raising awareness in rural areas. [15] found that education in whatever form brings about the inculcation of the right type of awareness, knowledge, attitude, and the capacity to change the perception of the farmers to engage in different activities which can prevent or mitigate climate variability in extreme conditions or situations.

The mean farm size cultivated by the respondents was 2.2 acres, and this indicates that more than half (68%) of the farmers cultivated below the mean farm size which was still small and can make them more susceptible and less equipped to handle the adverse effect of climate variability. This result upholds the findings of [2, 13], who found that households with larger lands dedicated to cultivation are more likely to employ a variety of adaptation strategies.

Table 1. Distribution of respondents based on socio-economic characteristics

| Socio-economic Variable | Frequency (n= 150) | Percentage | Mean |
|---|---|---|---|
| Gender | | | |
| Male | 94 | 62.7 | |
| Female | 56 | 37.3 | |
| Age | | | |
| 25-45 | 59 | 39.3 | |
| 46-65 | 63 | 42.0 | |
| 66-85 | 24 | 16.0 | |
| 86-95 | 4 | 2.7 | 48.0 |
| Household Size | | | |
| 1-3 | 39 | 26.0 | |
| 4-7 | 93 | 62.0 | |
| 8-11 | 14 | 9.3 | |
| 12-14 | 4 | 2.7 | 5.1 |
| Income on Farming | | | |
| 10,000-40,000 | 26 | 17.3 | |
| 41,000-80,000 | 49 | 32.6 | |
| Above 81,000 | 75 | 50.0 | 101,000 |
| Other source of income | | | |
| No other sources | 59 | 39.3 | |
| 10,000-40,000 | 40 | 26.6 | |
| 41,000-80,000 | 32 | 21.4 | |
| Above 81,000 | 19 | 12.6 | 35,015 |
| Level of education | | | |
| No formal education | 22 | 14.7 | |
| Primary education | 33 | 22.0 | |
| Secondary Education | 58 | 38.7 | |
| NCE/OND | 20 | 13.3 | |
| HND/B.Sc. | 17 | 11.3 | 3.83 |
| Arable crop planted | | | |
| Maize | 100 | 31.3 | |
| Groundnut | 19 | 5.9 | |
| Vegetable crop | 63 | 19.7 | |
| Tuber | 105 | 32.8 | |
| Rice | 10 | 3.1 | |
| Millet | 12 | 3.8 | |
| Beans | 11 | 3.4 | |
| Farm size | | | |
| Less than 1 Acre | 34 | 22.7 | |
| 1-2.5 | 68 | 45.3 | |
| 2.5-4.0 | 32 | 21.3 | |
| 4.1-6.0 | 16 | 10.7 | 2.2 |
| Access to extension services | | | |
| Yes | 45 | 30.0 | |
| No | 105 | 70.0 | 1.7 |
| **Farm experience** | | | |
| 1-10 | 45 | 30.0 | |
| 11-20 | 31 | 20.7 | |
| 21-30 | 45 | 30.0 | |
| Above 31 | 29 | 19.4 | 25.5 |

Source: Source: Field Survey, 2021.

Table 1 further demonstrates that the majority of farmers (70.0%) have access to extension agents, whereas 30.0% do not. This suggests that extension contacts determine the knowledge farmers will acquire about production activities and the deployment of innovations through counseling and demonstrations by extension agents, which may affect the farmers' ability to adapt to climatic unpredictability. This result is consistent with [16, 25] who discovered that information received through extension service delivery is helpful to farmers in that it can enable them to develop coping strategies for adverse weather conditions on plants, livestock and the farmers themselves.

**Farmers' perceptions of climate variability on crop production**

The distribution of responses regarding farmers' perceptions of climatic variability is shown in Table 2. Farmers believed that the impact of climatic variability has resulted in a drop in crop output (mean=4.3), they also revealed that rainfall doesn't start and end at the normal period of the year due to variations in climates and this has resulted to crop failure overtime (mean=4.1). Farmers expressed that an increase in temperature and drought has led to decreased in soil fertility and thereby affected crop production (mean=4.0). The Table further shows that more than half (52.0%) of the farmers strongly agreed that excess rainfall hardly supports crop production (mean=39) and 50.0% indicated abnormal temperature in recent time and this has affected crop yield (mean=3.8).

The conclusion is that most survey respondents have positive assessments of the impact of climatic variability on agricultural output in the study area, which may be due to their high experience in farming. Their perceptions of climate variability are important to adaptation as they determine decisions in agricultural planning and management. The result is consistent with [17], indicating that farming experience and educational level positively influence adaptation decisions in planning and management of their agricultural activities.

Table 2. Farmers' perceptions of climate variability on crop production

| Farmers' perception of climate variability | SA F (%) | A F (%) | UD F (%) | D F (%) | SD F (%) | M |
|---|---|---|---|---|---|---|
| Temperature is not normal in recent time | 75 (50.0) | 27 (18.0) | 14 (9.3) | 23 (15.3) | 11 (7.3) | 3.8 |
| Rainfall does not start and end at the normal period | 84 (56.0) | 28 (18.7) | 17 (11.3) | 11 (7.3) | 10 (6.7) | 4.1 |
| There is an increase in temperature and drought | 80 (53.3) | 30 (20.0) | 18 (12.0) | 12 (8.0) | 10 (6.7) | 4.0 |
| There has been an increase in the intensity and frequency of weather events | 59 (39.3) | 43 (28.7) | 29 (19.3) | 6 (4.0) | 13 (8.7) | 3.8 |
| There has been noticeable drying of streams and river | 72 (48.0) | 33 (22.0) | 23 (15.3) | 9 (6.0) | 13 (8.7) | 3.9 |
| All your crops have been failing due to the variations in climates | 81 (54.0) | 39 (26.0) | 17 (11.3) | 4 (2.7) | 9 (6.0) | 4.1 |
| Vegetation has been dried | 71 (47.3) | 40 (26.7) | 20 (13.3) | 10 (6.7) | 9 (6.0) | 4.0 |
| There has been decrease in crop yields | 96 (64.0) | 30 (20.0) | 8 (5.3) | 6 (4.0) | 10 (6.7) | 4.3 |
| There has been noticeable land degradation in the community | 44 (29.3) | 64 (42.7) | 27 (18.0) | 8 (5.3) | 7 (4.7) | 3.8 |
| There has been reduced soil fertility | 77 (51.3) | 33 (22.0) | 15 (10.0) | 14 (9.3) | 11 (7.3) | 4.0 |
| Excessive rain hardly supports crops production | 78 (52.0) | 38 (25.3) | 7 (4.7) | 8 (5.3) | 19 (12.7) | 3.9 |

*SA=Strongly Agreed, A=Agreed, UD=Undecided, D=Disagree, SD=Strongly Disagree, M=Mean*
Source: Field survey, 2021.

**Hypotheses testing**

The findings in Table 3 made it abundantly evident that there was no significant relationship between gender ($\chi2=46.5$, $p>0.05$), age ($\chi2=199.5$, $p>0.05$) religion ($\chi2=79.4$, $p>0.05$), education ($\chi2=247.6$, $p>0.05$) and experience ($\chi2=299.4$, $p>0.05$), and farmers adaptation strategies. However, there was a significant correlation between household size ($\chi2=179.3$, $p<0.05$), farm size

($\chi 2$=136.4, $p<0.05$) and farmers' adaptation techniques. The implication is that the rural farmers with larger households have a potentially higher labour force and are more likely to implement adaptation strategies. This is consistent with the findings of [23] who submit that larger household size is a positive determinant of household farm income that may enhance their adaptive capacities to combat variations in climatic conditions. The anticipated association between farm size and adaptability indicated that a large farm sizes provides farmers with room to implement more adaption techniques [12]. In a related study, [34] reiterated the role of farm size in influencing farmers' adaptation strategies.

Table 3. Chi-Square analysis of the relationship between selected socio-economic characteristics of respondents and the adaptation strategies

| Socio-economic characteristics | $\chi^2$ | P-value | Decision |
|---|---|---|---|
| Gender | 46.5 | 0.161 | Not Significant |
| Age | 199.5 | 0.913 | Not Significant |
| Household size | 179.3 | 0.034* | Significant |
| Farm size | 136.4 | 0.020* | Significant |
| Religion | 79.4 | .372 | Not Significant |
| Level of education | 247.6 | .117 | Not Significant |
| Years of experience | 299.4 | .563 | Not Significant |

**significant: $p<0.05$; $\chi^2$: Chi-square value; p-value: asymptotic significance value*

Source: Own results.

Table 4. Pearson Product Moment Correlation showing the relationship between perception of climate variability and adaptation strategies by the respondents

| Variable | r-value | p-value | Decision | Remark |
|---|---|---|---|---|
| Perception of climate variability | 0.591 | 0.000* | Significant | Ho rejected |

**Significant: $p < 0.05$*

The results obtained in Table 4 found that a significant relationship existed between the farmers' perception of climate variability ($r=0.591$, $p<0.05$) and their methods for adjusting to climate variability. The research demonstrates that farmers' perceptions are crucial to the effective use of adaptation methods to lessen the effects of climate variability on agricultural activities [18]. The result corroborated the findings of [8] as they pinpointed that any farmers who lack perception will experience a major setback by facing critical challenges for not responding to climate variability through adaptation.

## CONCLUSIONS

It could be inferred that farmers' perception of climate variability greatly influences adaptation strategies. Based on the findings of the study, we could have deduced that an increase in perception of climate variability will improve farmers' adaptation strategies thereby improving the value of their products, preventing the destruction of crops and farmland, and generally bring about improvement in the livelihoods of farmers, empower the farmers as well as having positive impact on the productivity, and reduce poverty level in the rural areas. Moreover, the result has shown that the household size and farm size have a big impact on farmers' adaption techniques.

Based on the study's findings, the following recommendations are made:

-There should be increased knowledge of and sensitivity to climate variability at the Local, State, and Federal government levels to have a community whereby the farmers are adeptly aware of the causes and effects of climate variability. Such awareness when put in place should modify the already existing perception of climate variability and at the same time create favourable adaptation measures appropriate and suitable for arable crops peculiar to the study area.

-Farmers should be exposed to more training and visitation from extension agent and all other relevant organizations and personnel to increase their awareness, knowledge, and insight on appropriate and affordable adaptation strategies that are suitable and relevant to their situation and circumstances.

-The farmers in the locality should also be exposed to new and emerging adaptation measures from research institutes scientifically proven to be effective for arable crops.

-Additionally, in order to effectively communicate knowledge to farmers, extension agents need to be given the necessary knowledge and skills in adaptation and coping mechanisms through frequent training programmes.

-All the three tiers of government in Nigeria (Federal, State, and Local) should try as much as possible to lessen the constraints experienced by the farmers by providing credits, irrigation facilities, and more extension officers on the field.

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# INCENTIVIZING THE ADOPTION OF BIOFORTIFIED RICE FOR INCREASING FARMERS' PRODUCTIVITY AND INCOME DURING COVID19 ERA: EVIDENCE FROM SMALLHOLDER FARMERS IN NIGERIA

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***Abstract***

*This research examined the challenges and factors affecting the behaviours of rice farmers towards adopting the bio-fortified rice technology in the Covid-19 pandemic era. The trust of the paper rests on despite the awareness and support to farmers to adopt the new bio-fortified rice technology and the importance of technology in farmers' welfare; the acceptance has been low and slow. More importantly, research in this area has neglected the factors influencing the adoption of biofortified rice and its impact on the production and income of the farmers in Nigeria during the pandemic era. This study used a multi-stage sampling procedure to select 540 (200 non-adopters and 340 adopters) rice, farmers. Data were collected using computer-assisted personal interviews (CAPI) and analyzed with descriptive and inferential statistics. The major result shows that the socioeconomic profiles of the adopters were better than the non-adopters. The decision by the farming households to adopt biofortified rice was significantly influenced by the household's income level, extension agent contact, credit, association with cooperatives and availability of information. In addition, adopting biofortified rice increased the adopters' income across all categories of inc12ome considered. The rice farmers faced general and specific Covid-19 challenges that constrained them from adopting the technology. It was recommended, among others, that emergency agencies whose duties are to mitigate the effects of a pandemic-related crisis should have offices in the rural areas to have close contact with the information needs of the rural farmers in times of emergency.*

**Key words**: *bio-fortified rice, challenges, innovation, Covid-19, Nigeria*

## INTRODUCTION

The world's second most popular cereal (after wheat) rice shapes the lives of millions of households worldwide. Rice accounts for about 80% of the world's food calorie requirements for more than half of the world's population [3, 13]. In Nigeria, it is a staple food that is consumed across all social divides, including poverty status, religion, tribe, and gender [18]. Growing population and income levels, in conjunction with the ease of preparing and storing it, could explain the rise in demand [3]. Rice production is characterized by peak seasonal labour demand and labour-intensive production, which made labour shortages a serious problem despite agricultural production being exempt from COVID-19 lockdown. The COVID-19 pandemic has brought a new risk to Nigeria's rice farmers, who are already facing the negative impact of climate change and greenhouse gas (GHGs) emissions [13, 17].

The Coronavirus (Covid-19) pandemic has created a landmark impact on food production since 2019, and virtually all aspects of the economy are expected to adjust to this effect, therefore demanding that more innovative innovations be adopted to cushion the challenges before us. At the beginning of the crisis, the food supply chains were constrained by domestic and international lockdowns, affecting the production and distribution of staple food like rice [11, 12]. Reduced rice production may have severe implications for staple food availability. The negative effect of the rice supply and demand chain by Covid-19means that farming household swill not be able to access a sufficient nutritious food supply thereby facing the worst food insecurity conditions [17]. Therefore, the pandemic has occasioned the need not just for increased rice production but, most importantly, the need for the intake of fortified gramineous plants at a reduced cost. Due to the rice endosperm is deficient in many nutrients, including vitamins, proteins, and micronutrients, fortification becomes important in fighting nutrient deficiencies through gramineous practices [45]. The Aleurone layer of the dehusked rice grain is a nutrient reach but is lost during milling and polishing. Therefore, this study investigates farmers' behaviour, productivity and challenges towards adopting this innovation in the Covid-19 pandemic era. Graminaceous plants, such as rice, have sophisticated mechanisms for acquiring micronutrients from soil and absorbing them from roots to grains by secreting small molecules called mugineic acids (MAs) such as *copper* (*Cu*), *manganese* (*Mn*), iron (*Fe*), and *zinc* (*Zn*)which are acceptable for use [45]. Sequel to this, the Nigerian government approved the adoption and expansion of bio-fortified rice targeted at improving its dietary intake and increasing local production [31]. However, this research is motivated by the fact that both field observations and literature suggest that the current Covid-19 pandemic has widened the gap between the demand and supply of locally produced nutrient-filled rice [4,5, 44]. Before the pandemic, the adoption of biofortified rice variety by the local farmers was still low and slow, which led to the production of staples with low micronutrients (vitamin *A*, iron and zinc) [45,27]. Consequently caused Nigeria to import rice (2,000,000MT in 2017, 1,900,000MT in 2018 and 1,800,000MT in 2019) despite all the measures taken by the government to increase local production [30]. [3] further noted that the most common micronutrient deficiencies found to be lacking in staples in Nigeria include vitamin *A*, iron, and zinc, with the prevalence rates of 29.5%, 26%, and 20%, respectively, in children less than five years. Also, micronutrient deficiencies such as lack of vitamin *A* have contributed significantly to estimated 600,000 child mortality worldwide, and lack of zinc contributes to about 400,000 deaths in children annually. In Nigeria alone, it has been statistically estimated that 25% of children under six years of age suffer from vitamin A *d*eficiency, which causes poor growth [2]. These problems could also lead to increased maternal and infant deaths. Studies have also shown that deficiency of vitamin *A* has caused 964,000 Disability Adjusted Life Years (DALYs) in Nigeria; this vitamin *A* dietary intake was inadequate in about 83% of preschool-aged Nigerian children [45, 2].

Closing these gaps (of poor yield and low micro-nutrient supply) as quickly as possible in this post-pandemic era depends mainly on farmer's acceptability of this innovation, increased consumer preference for the new product, access to farmers' credit, increased farmer education, and expanded extension services [27], as well as consistent and appropriate policies. Evidence of the poor, inconsistent, and inappropriate policies is clearly shown during the ban on rice importation. Nigeria was still importing thousands of tonnes of rice through many of her illegal trade routes. In the same line of thought, many research works have been done to investigate these rice production gaps without attempting to investigate the behaviour of farmers towards adopting this innovation and the major problems hindering its full adoption, especially in this pandemic crisis. Therefore, this present study aims to compare the socioeconomic attributes and input/income levels of adopters and non-adopters, determine the factors influencing farmers' behaviour towards bio-fortified rice production technology in the pandemic era, identify general constraints limiting the adoption of bio-fortified rice technology in Nigeria, and identify specific constraints associated with Covid-19.

## MATERIALS AND METHODS

The study area is Nigeria, comprising northern and southern parts with distinctive rainfall patterns. Nigeria is located in West

Africa and lies in the northern latitudes between $4^0$ and $14^0$ and between $3^0$ and $15^0$ of the eastern longitude [19]. It has a 923,768 sq.km landmass and comprises 36 states and the Federal Capital Territory, 2 major regions (north and south), and six sub-regions in Figure 1 below. It is bordered to the north by the Republics of Niger and Chad. Nigeria's irrigated land is 9,570 $km^2$, while the arable land is about 35% of the total land area [3,2]. The major soil types in Nigeria have the potential for agriculture. Nigeria recorded 140,431,790 people in the 2006 national census but is estimated to have reached 200 million in 2019 [25]. Also, according to [26], Nigeria holds 182,000 cases and 2,520 deaths out of 178m cases and 3.86m deaths of the Coronavirus pandemic globally. Figure 1 shows the update of Covid-19 cases in Nigeria.

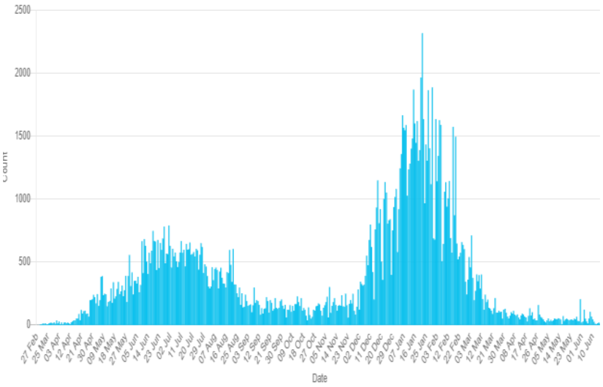


Fig. 1. Nigeria’s update of Covid-19 cases till January 2021
Source: NCDC, 2021.

According to data from [25], food insecurity and unemployment are becoming more pronounced during this pandemic era, with the average poverty in Nigeria's headcount becoming the highest in Africa. According to [39], rice is the major staple produced in Nigeria, and as indicated in [16] it has served as an “object of food security”. There are wide varieties of paddy rice grown in Nigeria. These varieties include FARO 14, 15, and 44, ITA 306 and 316, Mass 1 and 2, and NERICA, among others [3]. These are considered 'traditional' varieties because the farmers have been producing the varieties over the years. A newly introduced bio-fortified variety is also genetically improved with minerals and vitamins. In line with many efforts to reduce the menace of micronutrient deficiency, the Nigerian government, in collaboration with a broad spectrum of stakeholders, has been subsidizing the supply of bio-fortified rice seeds. This intervention is expected to increase productivity and reduce nutrient deficiency among women and children. According to [10], Nigeria has seen remarkable progress in rice production in the past ten years, with growth rates of 1.3% and 2.3% for 2018 and 2019, respectively.

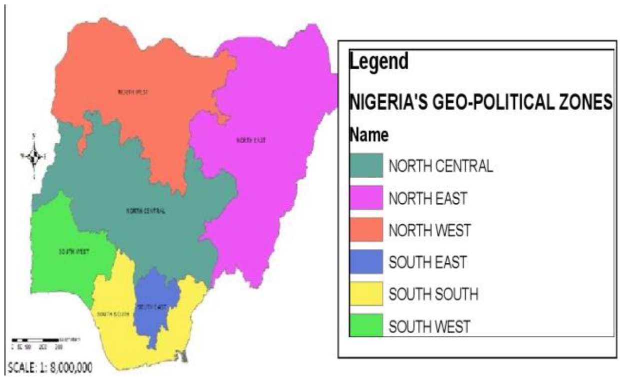


Fig. 2. Map of Nigeria showing north (northwest, northeast, and north-central) and south (east, southwest, and south-south).
Source: Google Maps.

There are many varieties of paddy rice grown in Nigeria. These varieties include FARO 14, 15, and 44, ITA 306 and 316, Mass 1 and 2, and NERICA, among others [20,38]. These are considered 'traditional' varieties because the farmers have been producing the varieties over the years. A newly introduced bio-fortified variety is also genetically improved with minerals and vitamins. In line with many efforts to reduce the menace of micronutrient deficiency, the Nigerian government, in collaboration with a broad spectrum of stakeholders, has been subsidizing the supply of bio-fortified rice seeds. This intervention is expected to increase productivity and reduce nutrient deficiency among women and children. According to the [37,45], Nigeria has seen remarkable progress in rice production in the past ten years, with growth rates of 1.3% and 2.3% for 2018 and 2019, respectively.

***Sampling***

Multi-stage sampling procedures involving purposive and random sampling techniques were used to select respondents for this study Figure 2).

Nigeria was delineated into northern and southern regions in the first stage for administrative convenience. Three states were purposively selected from each region based on their relative dominance in rice production. Ebonyi, Anambra, and the Enugu States were selected in the southern part, while Adamawa, Gombe, and the Taraba States were selected from the northern part. The second stage involved selecting two Local Government Areas (LGAs) that are dominantly involved in rice production from each of the six states, totalling 12 LGAs. In the third stage, communities were selected in proportion to the number of rice farming villages in the LGAs.

The proportionality factor adopted for the study is shown thus:

$$\mathrm{Xi} = \frac{\mathrm{n}}{\mathrm{N}} * 100 \quad \ldots\ldots(1)$$

where:

*Xi*= number of rice farming communities sampled in each LGA

*n*=number of farming communities in a particular LGA

*N*= Total number of farming communities in all the selected LGA.

From a list of biofortified rice farmers, 20 rice-producing communities were randomly selected. From the list, 15 households that have access to biofortified rice and use it were selected at random, and 5 households that have access to biofortified rice and did not use it were randomly chosen, making a total of 620.

However, only 540 instruments (340 adopters and 200 non-adopter) were completed, retrieved, and collated using computer-assisted personal interviews (CAPI).

***Binary Logit Model***

The Logit model was used to achieve objective two of this study. The empirical model is specified thus:

$$\mathrm{Y}_i = \frac{1}{X_{ij}} = (\mathrm{F}\,(Z_i)) = (1/1 + \mathrm{e}^{-\mathrm{zi}} = \mathrm{e}^{\mathrm{z}}/\mathrm{e}^{\mathrm{z}} + 1) \quad \ldots\ldots(2)$$

where:

$$\mathrm{Y}_i = \mathrm{Z}_i = (\alpha, \beta_1 X_{1j}, \beta_2 X_{2j}, \ldots \beta_8 X_{8j}), \varepsilon$$

$Z_i$ is the theoretical likelihood of the sample formed by introducing a dichotomous response variable $Y_i$ such that $Y_i$ is either 0 or 1.

$Y_i$= 1 if the $i^{th}$ farmer is an adopter of bio-fortified rice farming innovation

$Y_i$ = 0 if the $i^{th}$ farmer is a non-adopter of bio-fortified rice farming innovation

j = 1- 8 variables in Table 1

i = 1 to 540 (total number of respondents)

$X_{ij}$= socioeconomic and institutional profiles of the $i^{th}$ farmers as in Table 1.

$\beta_1$to $\beta_8$are parameters of estimates from the variables under study

$\alpha$ = constant term

$\varepsilon$ = disturbance term.

***Variable specifications in the model***

The measure of innovativeness developed for this study was based on the number of farmers who had adopted the fortified rice innovation. Given that nearly all the farmers had adopted at least one innovative technology, such as improved seed varieties, fertilizer, herbicide, and/or insecticide, the respondents were classified into two categories of innovativeness: non-adopters and adopters.

Table 1. List of variables used in the study

| SN | Variable | Variable code | Description and unit | *A priori* |
|---|---|---|---|---|
| 1 | Households' farm income | Income ($X_1$) | Revenue from farming (Naira) | + |
| 2 | Access to information | Info ($X_2$) | Number of extension visits (number of visit) | + |
| 3 | Access to credit facilities | Credit ($X_3$) | Reasonable loan Obtained to finance farming operation (Yes, 1; No, 0) | +/- |
| 4 | Educational status | Literacy ($X_4$) | Years of formal education attained (years) | + |
| 5 | Farming experience | Exp ($X_5$) | Period of years engaged in rice farming (years) | +/- |
| 6 | Total farm size | Size ($X_6$) | The a priori expectations for the variables (hectares) | + |
| 7 | Household size | People ($X_7$) | Individuals in a household (number) | +/- |
| 8 | Membership of cooperative group | Club ($X_8$) | Membership of cooperative groups (If affiliated = 1, 0 otherwise, | + |

Source: Authors' conception.

A farmer is said to be an adopter if the farmer fully adopts the bio-fortified rice innovation.

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Based on the previous, 200 farmers were identified/ classified as adopters, and 340 were identified/classified as non-adopters. This provides a valuable basis for empirical analysis of the underlying factors contributing to a farmer's decision to adopt the new farming techniques. The *apriori* expectations for the variables, codes and units as used in this study are described in Table 1.

***Pre-estimation tests***

Before using the logit model, multi-collinearity was checked to exclude any highly correlated explanatory variables. The results indicated low and tolerable levels of multi-collinearity in the data using Variance Inflation Factor (VIF), and condition index (CI). Multi-collinearity is more troublesome if there is a larger value of VIF. As a rule of thumb, if the VIF of a variable exceeds 10, the variable is said to be highly collinear [43].
Following [43], the $VIF_j$ is given as:

$$VIF (X_j) = 1/1 - R^2 j \quad \text{………….............(3)}$$

where:
$R^2$ j is the coefficient of multiple determinations when the variable $X_j$ is regressed on the other explanatory variables. There may also be interaction between categorical (dummy) variables, which can lead to the problem of multi-collinearity. To detect this problem, Phi (φ) coefficients were computed.
The Phi (φ) coefficient was compounded as follows:

$$\varphi = \sqrt{\chi 2} / n \quad \text{………….......................... (4)}$$

where:
φ is the phi coefficient; χ2 is chi-square test and n = total sample size.
If the value of the Phi coefficient is greater than 0.5, the variable is said to be collinear [43].

***Computing household income***

In this study, the biofortification program's adoption was determined by its adopters' income gains. Some studies have found that directly measuring income is laborious [43]. Expenditures have been used as a proxy instead of household income. Despite these arguments, the study used three monetary measures: household income, total income, agricultural income, and per capita income. By asking the sampled households to disclose their monthly monetary income by source, we could estimate the income of the households in the sample. In this way, income data could be improved. In order to calculate each income source's contribution to the cash, we use the following equations:

$$Y_i = \sum y_{i,k}$$
$$y^*_{i,k} = \frac{y_{i,k}}{Y_i} \quad \text{……………................. (5)}$$

The following formula was used to calculate household daily per capita income.

$$PCI_i = \left(\frac{Y_i/365}{Hs_i}\right) \quad \text{.................................. (6)}$$

For the first step, the household total income was divided by 365 in order to calculate the household daily income. Using this income, we can determine the household daily per capita income by dividing it by the household size, Hs. Rice-producing households were compared based on their household daily per capita incomes. Additionally, it provided an indication of the poverty status of the households. We estimated household income following the adoption of biofortified rice using the treatment effect estimation approach. In addition to being counterfactual-based, this method of estimating impacted outcomes also produced consistent estimates [43].
Farmers' adoption status is reflected by Y, while outcomes are reflected by T. Using the counterfactual framework, adopting a biofortified rice variety can result in two potential outcomes (i.e. Y = Y1 if T = 1 and Y = Y0 if T = 0). The average effect of adoption, also referred to as the average treatment effect, ATE, is generally calculated as follows:

$$ATE = E(Y_1 - Y_0) \quad \text{……….......................... (7)}$$

As a result of differences in knowledge, access to information, and physical accessibility, [7] anticipated unequal adoption opportunities. As a result of adoption status, the average treatment effect on the treated ATT can be expressed as follows:

$$\text{ATT} = \text{E}\big((\text{Y}_1 - \text{Y}_0) \mid \text{T} = 1\big) \ldots\ldots\ldots\ldots(8)$$

To adopt biofortified rice, access to the product was the most important factor. However, despite having access to seeds, some farmers may not have planted them.

This implies that some farmers complied while others did not. In this case, the local average treatment effect (LATE) measures the impact on the farmers who received seeds and planted them. According to LATE, the following parameters were used:

$$\text{LATE} = \text{E}\big((\text{Y}_1 - \text{Y}_0) \mid \text{P} = 1, \text{T} = 1\big) \ldots(9)$$

***The Econometric Procedures***

The study assumed that some exogenous factors also influenced the adoption of biofortified rice, $X$, such that the following formulas could calculate potential adoption outcomes; in terms of $X$ and the unaccounted factor, $\mu$, was given by:

Some exogenous factors may influence the adoption of biofortified rice, $X$, so the following formulas calculated potential adoption outcomes; in terms of and the unaccounted factor, $\mu$, was given by:

$$\text{Y} = \text{Y}_1 = \text{X}\beta_1 + \mu_1 \text{ if } \text{T} = 1$$
and
$$\text{Y} = \text{Y}_0 = \text{X}\beta_0 + \mu_0 \text{ if } \text{T} = 0$$

With these, the LATE was re-expressed as:

$$\text{LATE} = \text{X}\beta_1 - \text{X}\beta_0 + \text{E}(\mu_1 - \mu_0 \mid \text{X}, \text{T} = 1, \text{P} = 1) \ldots\ldots\ldots\ldots (10)$$

Subsequently, the observed income, $Y = Y_1 + Y_0$, was expressed in terms of the LATE as:

$$\text{Y} = \text{X}\beta_0 + \text{T} * \text{LATE} + \varepsilon_{\text{LATE}} \ldots\ldots\ldots (11)$$

A two-stage instrumental variable regression procedure was used to estimate the LATE parameter. An adoption model was estimated with access to seeds of biofortified rice, P, as an instrument, $W$, as additional explanatory variables, and $\gamma$ as coefficient estimates in the first stage. The model is specified as follows:

$$\text{Prob}(\text{T} = 1) = \Phi(\text{PW}\gamma) \ldots\ldots\ldots\ldots (12)$$

The estimation of the LATE model with the predicted probability of adoption is the second stage in the analysis process. The model was also specified as:

$$\text{Y} = \text{X}\beta_0 + \widehat{\text{T}} * \text{LATE}(\text{X}) + \varepsilon_{\text{LATE}} \ldots\ldots\ldots (13)$$

## RESULTS AND DISCUSSIONS

The result of this research is presented below in line with the study objectives.

**Rice production factors and socioeconomic characteristics of rice farmers in Nigeria**

The respondents (rice farming households) were categorized into two groups – adopters and non-adopters of bio-fortified rice technology. A comparative summary of their resource inputs and major socioeconomic characteristics showed that the population of adopters was 37%, while non-adopters stood at 63% (Table 2). This suggests that the level of adoption among rice farmers in Nigeria is still relatively low, despite all the efforts by the government and other stakeholders. This is in line with other studies Such as [36, 14], which further opined that farmers could be critical in accepting new varieties to preserve the cherished indigenous or traditional rice varieties. The findings also showed adopters had better socioeconomic attributes such as higher rice output, less dependence on family labour, higher income, use of more paid labour, use of more fertilizer and herbicide, higher educational attainment and more number of extension visits [1]. All these may have contributed to their positive behaviour towards adopting the new technology more than their counterparts.

Though the research expectation was that more farming households would have adopted the technology, there is a general belief that any technology introduced and supported by the government is for their good. Also, the *apriori* expectation of this study was based on the research by [4], that judicious use of technologies improves efficiency. However, maybe because improved technology is expected to come with costs, risks and uncertainty, only farming households with better supporting attributes ventured into adopting bio-fortified rice technology. In line with this finding, [16] also noted that farmers who adopt better technologies had better chances of selling at a better price, thus, having a better socioeconomic outlook. Also, many other researchers believe that technology influences farmers' participation behaviour [14].

This study also showed that adopters were more economical with the bio-fortified rice seedlings than the non-adopters using the traditional seedlings in terms of planting and spacing. The seed rate of 60kg/ha on average was used by adopters, which is closer but slightly below the FAO-recommended 80kg/ha. In comparison, the non-adopters with an average seed rate of 102kg/ha planted even more than the recommended rate. This difference could be attributed to the adoption or use of the new seed is costlier than the existing species, and the non-adopters planted the traditional varieties obtained or sourced from the previous year's harvest. This is also supported by [15], who noted that the quantity and quality of rice seed planted by farmers depend on the price per kg, seed varieties, and technology access, among others. However, the recommended quantity of seed per hectare of upland and lowland rice production system was put at 100kg/ha [37]

Lastly, on the socioeconomic characteristics of the adopters and non-adopters, there were significant differences in farm income, education and extension visits at 1% level. However, their age, household size and farming experience were closely the same. This suggests that a number of extension visits/training, income and education levels were some of the major issues affecting their decision to adopt or not.

Table 2. Summary statistics of Rice Production Inputs and Socioeconomic Characteristics of the Paddy Rice Farmers

| Variables | Adopters | | Non-adopters | | P > T |
|---|---|---|---|---|---|
| | Mean | St.Dev. | Mean | St.Dev. | |
| Paddy rice output (kg) | 2633.5 | 1537.2 | 1593.9 | 837.6 | 0.00*** |
| Farm size (Ha) | 1.2 | 0.6 | 0.9 | 0.5 | 0.00*** |
| Rice Seed (kg) | 59.6 | 35.6 | 102.2 | 42.2 | -0.65 |
| Household’s labour (man-days) | 46.0 | 63.5 | 65.5 | 65.3 | -0.43 |
| Paid labour (man-days) | 60.0 | 64.7 | 25.2 | 55.8 | 0.05** |
| Fertilizer (kg) | 149.4 | 96.7 | 83.9 | 47.8 | 0.01*** |
| Herbicide (liters) | 3.0 | 1.7 | 1.1 | 0.9 | 0.00*** |
| Monthly Income (N) | 29,291.61 ($68.12) | 10451.6 | 15,148.91 ($35.23) | 5899.8 | 0.00*** |
| Age (years) | 34.6 | 6.6 | 51.6 | 11.7 | -0.21 |
| Household size (number) | 7.7 | 6.2 | 14.4 | 8.4 | -0.32 |
| Educational level (years) | 7.5 | 5.6 | 3.8 | 4.9 | 0.00*** |
| Extension contact (number) | 7.6 | 2.5 | 2.4 | 2.3 | 0.00*** |
| Farming experience (years) | 12.6 | 6.31 | 12.0 | 5.9 | 0.65 |
| number of observation | 200 | 340 | - | | |

*** Significant at 1% ** Significant at 5%, SD = Standard Deviation.
Source: Field survey, 2021.

This is also related to the study of [19, 21], which emphasized that education, extension contact, age and family size are some of the main determinants of technical efficiency among rice farmers in Nigeria and Ghana, respectively. Also, [20] stated that the same socioeconomic characteristics contribute 38% of the variation in rice output.

**Income of adopters and non-adopters of biofortified rice in Nigeria**

Using descriptive statistics shows that there is a significant difference between the adopters and non-adopters of biofortified rice across all the income categories (Table 3). For instance, the total monthly income of adopters and non-adopters of biofortified rice farmers were N15,148.91($35.23) and N29,291.61($68.12), respectively. In addition, the average percentage change for adopting biofortified rice was 88% for all income categories, suggesting a significant improvement in adopters' income. However, rice farmers' monthly average per capita and average monthly income increased by 47% and 74% for adopting and not adopting biofortified rice, respectively. It is also important to note that daily per capita income for adopters and non-adopters were N2175.80 ($5.06) and N3,198.43 ($7.49), respectively. This result suggests a wide variation in the income distribution of households as a result of the adoption of biofortified rice. Similar result was reported by [7, 24]. Who reported a significant increase in income of rice adopters in Ghana [14, 8]. However, this result will be tested with instrumental variable analysis to identify the Local Treatment Effects (LATE) to approve or reject the effect of adoption on farmers' income.

Table 3. Incomes of sampled adopters and non-adopters of biofortified rice

| Activities | Non-adopters | Adopters | % Change | t-cal> \|t\| |
|---|---|---|---|---|
| Daily per capita income | N2175.80 ($5.06) | N3,198.43 ($7.49) | 47% | 0.00 |
| Total income (Monthly) | N15,148.91 ($35.23) | N29,291.61 ($68.12) | 93% | 0.00 |
| Rice Income (Monthly) | N8,432.30 ($19.61) | N14,645.80 ($34.06) | 74% | 0.00 |
| Total agricultural Income (Monthly) | N11,360.66 ($26.42) | N21,973 ($51.10) | 93% | 0.01 |

Source: Computed from field data.

**Determinants of the adoption of bio-fortified rice among the farmers in Nigeria**

The result only reported the LATE values. This is because the OLS estimation of the impact parameters had no significant results, and there was a positive selection bias. Other treatment effect estimators improved results. OLS models with an interaction between adoption status and other covariates in the model solved the problem of selection bias. Except for rice income, where adoption had a significant positive impact on adopters, there was no significance in all other income categories. In addition, PSM eliminated selection bias in outcomes associated with positive adoption status. There was no statistical significance among any of the estimated impact outcomes. The study then applied access to biofortified rice as an instrument to correct for endogeneity in adoption; the estimated LATE parameters were significant for all the income categories and were discussed.

A binary logistic regression model was used to examine the factors influencing the adoption of the new rice production technology. The farmers were classified into adopters and non-adopters of new rice production technology. Eight possible determinants of rice production technology were used as the exogenous variables. The result of the likelihood ratio estimated indicated that all the Chi-square statistic was significant ($p < 0.001$), which suggests that the models were adequate for explaining the determinants of improved technology in rice production. This also shows that the model fits the data.The overall test shows that socioeconoimc characterisitics significantly affected the farmers' decision to adopt the rice production technology. In addition, about 55% of the total variation for adopting bio-fortified rice farming innovation were explained by independent variables. The marginal effects of the logit regression are presented in Table 4.

From the result, the decision by the farming households to adopt the bio-fortified rice farming innovation was significantly influenced by the household's level of income ($p<0.001$); this indicates that a unit increase in the households' income increased the likelihood of the farmers' innovativeness towards adopting the technology. It was expected that as farmers' income rises, the respondents would have more capital to invest, thereby having more capacity to take risks associated with adopting new

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technology. This is in consonant with findings of [26]. However, [29] reported that income alone does not guarantee adoption of biofortified rice farming, according to the author, it is only when the superior intention of the farmers to adopt based on income supersedes social benefit that makes income has significant influence. The coefficient of access to credit facilities was also positive and significant (P<0.001). The significance of the variable stemmed from the fact that access to agricultural credit is an important factor in making decisions about innovation adoption. Some studies support this finding [16, 22, 41]. These researchers argued that the fungibility of funds could deter its importance in adopting new technology.

Furthermore, access to extension officers (the number of visits by the extension agents to farmers) was positively significant (P<0.005). This means that skills and knowledge gained from the extension officers can influence Farmers' decisions to adopt new technologies [20, 1]. Membership of farm clubs or organizations such as cooperative societies had a positive and significant (p<0.01) influence on the adoption behaviour of rice farmers.

This agrees with [19, 26], who opined that membership in farm groups should be an added advantage in gaining access to information, credit, and skills.

Table 4. Parameter estimates of the Binary Logit regression of major factors influencing the adoption of bio-fortified rice innovation

| Variables | Coeff. | Standard error | Wald | Significance | Exp (B) |
|---|---|---|---|---|---|
| Constant | -3.71 | 1.90 | 4.9 | 0.00*** | 0.0 |
| Income | 0.11 | 0.02 | 20.3 | 0.00*** | 2.5 |
| info | 0.82 | 0.21 | 22.8 | 0.00*** | 2.3 |
| credit | 3.90 | 0.90 | 19.6 | 0.00*** | 0.0 |
| Edu | 0.21 | 0.19 | 5.2 | 0.07 | 1.2 |
| exp | -0.00 | 0.11 | 0.0 | 0.28 | 1.1 |
| h-size | 0.10 | 0.72 | 0.0 | 0.14 | 1.2 |
| Extension | -0.30 | 0.21 | 5.1 | 0.00** | 0.8 |
| farm clubs | 2.21 | 0.82 | 6.7 | 0.00*** | 1.1 |
| number of observations | | | 540 | | |

*** Significant at 1%; ** Significant at 5%;-2 log-likelihood 61.548
Chi-square ($\chi 2$) 294.359***; Predicted Adopter 54%; Non-adopter 56.5%; Overall 55.3%.
Source: Field survey, 2020/21.

**Constraints limiting the adoption of bio-fortified rice technology in Nigeria**

The multiple responses from the farmers are presented in Table 5, and it shows the ranking order of the major constraints limiting the adoption of bio-rice technology in Nigeria. The result indicates that the most critical constraints faced by the farmers in order of seriousness were poor access to affordable and reliable farm inputs, inadequate credit facilities, conflicts with Cattle grazing nomads, and activities of middlemen. A similar result has been found elsewhere [21]. In addition, a study by [34] indicated that though access to input could be a critical factor in adoption, farmers are often discouraged from adopting when adulteration of the same input fills the market. The paper advocates the direct provision of new seed technology to farmers without passing it through middlemen. In addition, herders have remained the major concern of crop farmers in North Central and Southern Nigeria [2]. Other constraints were inadequate extension support, rainfall, and unfavourable land tenure systems. The result shows that some challenges were critical (above 50%). For instance, the majority of rice farmers (96.3%) were faced with poor access to affordable farm inputs (ranked first most critical challenge), while 90.8% were constrained by inadequate credit facilities (second most critical challenge). Also, the consistent conflicts between crop farmers and herders (89%) ranked third most critical factor. This was followed by economic activities of the middlemen (82%), attacks by birds (77%) and inadequate extension services (74%).

Table 5. Critical constraints limiting the adoption of bio-fortified rice technology in Nigeria

| Constraints | Number of farmers | % | Rankings |
|---|---|---|---|
| Poor access to affordable farm inputs | 260 | 96.31 | 1 |
| Inadequate credit facilities | 245 | 90.75 | 2 |
| Conflict with grazing nomads/herdsmen | 240 | 89.00 | 3 |
| Activities of middle-men | 220 | 82.45 | 4 |
| Covid-19 pandemic | 210 | 77.75 | 5 |
| Inadequate extension support | 200 | 74.08 | 6 |
| Inadequate rainfall | 102 | 37.78 | 7 |
| Land tenure problems | 80 | 29.63 | 8 |

Source: Field survey (2021).

These findings are in line with [41, 42], which identified inadequate credit, inaccessible roads, inadequate extension support, inaccessibility to cheap farm inputs, high cost of transportation and birds' invasion as significant constraints faced by rice farmers.

**Impact of the adoption of biofortified rice on household income**

The result only reported the LATE values. This is because the OLS estimation of the impact parameters had no significant results, and there was a positive selection bias. Other treatment effect estimators improved results. OLS models with an interaction between adoption status and other covariates in the model solved the problem of selection bias. Except for rice income, where adoption had a significant positive impact on adopters, there was no significance in all other income categories. In addition, PSM eliminated selection bias in outcomes associated with positive adoption status. There was no statistical significance among any of the estimated impact outcomes. The study then applied access to biofortified rice as an instrument to correct for endogeneity in adoption; the estimated LATE parameters were significant for all the income categories and were discussed.

The result shows that across all income categories, the estimated LATE parameters were significant when using access to biofortified rice seeds as an instrument to correct endogeneity problems (Table 6). Rice income increased by USD 0.24 for farmers with access to and planted biofortified rice seeds. In addition, their agricultural income rose by USD 0.30 while their total agricultural income improved by USD 0.73. The per capita income rose by 0.001 as a result of the adoption.

Table 6. Impact of biofortified rice seeds on across farmers' income categories

| Parameters | Rice Income | | Agricultural income | | Per capita income | | Total Income | |
|---|---|---|---|---|---|---|---|---|
| | Coeff | P>\|t\| | Coeff | P>\|t\| | Coeff | P>\|t\| | Coeff | P>\|t\| |
| ATT | 31.67 | 0.42 | 102.00 | 0.27 | 0.24 | 0.30 | 178.08 | 0.29 |
| ATE | 22.30 | 0.66 | 131.01 | 0.37 | 0.09 | 0.27 | 120.08 | 0.34 |
| ATU | 2.87 | 0.83 | 93.00 | 0.51 | 0.06 | 0.43 | 107.27 | 0.59 |
| Selection Bias | 21.53 | 0.65 | 11.73 | 0.81 | 0.13 | 0.33 | 32.13 | 0.75 |
| LATE | 103.65 | 0.00 | 313.04 | 0.00 | 0.31 | 0.00 | 329.00 | 0.00 |

Source: Computed from field survey (2021).

This result is supported by [23, 8], who report that adoption has a significant increase in the income of the farmers.

**COVID 19-related constraints to adoption of bio-fortified rice technology**

Weighted mean, standard deviation and rankings were used to examine the decision on the level of agreement by the respondents on each element of the COVID-19 pandemic constraints. [40] used a similar methodology because of the unavailability of empirical data. The element with the highest weighted mean ranked first and was considered the element with the highest agreement (influence) by the respondents as the most challenging to adopt bio-fortified rice

technology. Any element with a standard deviation below 1.96 indicates that the respondents were not far from the mean and the opinion of one another, while elements with a standard deviation above 1.96 indicate that the respondents were far from the mean and the opinion of one another. Table 7, shows that the inability of the farmers to access inputs (fertilizer, chemicals, and labour) due to the covid-19 lockdown was the highest-ranking element (with a mean of 4.0) that prevented the farmers from using the new technology. The result is supported by [41, 6].
The second highest element (with a mean of 3.86) associated with the COVID-19 pandemic was the farmers' inability to access markets to sell off harvested paddy rice due to the lockdown. Though the result is supported by [32,9], other studies suggested different results where access to the market is not a major obstacle to selling their products during a pandemic [23, 35]. The fact that although during the lockdown, agricultural input was given the concession to move from one location to another, their movement was limited because some places that were observing strict COVID_19 protocols [33, 10].
As expected, the third most influential elements of the Covid-19 constraints were risks and uncertainties associated with the pandemic (3.85), followed by price/market instability (3.84). Fear of contracting the covid-19 disease from other people (3.47) ranked 5th. The low access to finance and stiffer measures to loan applications during the pandemic (3.30), the perishable nature of paddy rice (2.7), no access to extension officers due to lockdown orders (2.60), and the exploitative activities of the middlemen during the pandemic (2.59) ranked 6th, 7th, 8th, and 9th respectively.

Table 7. Elements of the Covid-19 pandemic constraints

| S/N | Covid-19 Pandemic constraints | Mean | SD | Rank |
|---|---|---|---|---|
| 1 | Inability of the farmers to access inputs (fertilizer, chemical, labour) due to covid-19 lockdown | 4.0 | 0.00 | 1st |
| 2 | Inability of the farmers to have access to markets to sell off harvested paddy due to lockdown | 3.86 | 0.46 | 2nd |
| 3 | Fear of contracting the covid-19 disease from other people | 3.47 | 0.75 | 5th |
| 4 | No access to extension officers due to lockdown orders | 2.60 | 0.81 | 8th |
| 5 | Low access to finance stiffer measures to loan application due to the pandemic | 3.30 | 0.52 | 6th |
| 6 | Price/market instability | 3.84 | 0.36 | 4th |
| 7. | Perishability nature of paddy rice | 2.74 | 0.94 | 7th |
| 8 | Exploitative activities of the middlemen during the pandemic | 2.59 | 0.24 | 9th |
| 9 | Absence of incentives/palliatives to cushion the effects of the lockdown | 2.30 | 0.22 | 10th |
| 10 | Risks and uncertainties associated with the pandemic | 3.85 | 0.34 | 3rd |

*SD – standard deviation
Source: Own results.

The least influential element associated with the pandemic was the absence of incentives/palliatives to cushion the effects of the lockdown (with a mean of 2.30). Although other studies supported this result [28, 15], the ranking was different in some other studies [22, 42].
The COVID-19 protocols for average rural farmers that were not educated increased the inability to access or observe pandemic protocols in the banking hall. This is enough limitation, as reported by [12].

## CONCLUSIONS

The outbreak of the Covid-19 pandemic in December 2020 brought an abrupt halt to most economic activities, including farming. The pandemic also highlighted the need for the consumption of sufficient macronutrients, especially in staple foods like rice. However, despite the government's awareness and support, as well as the immediate need for an increase in bio-fortified rice intake, the adoption is still low, and farmers are still risk averse to adopting this new technology even when they have access. This results in financial instability and a general lowered standard of living occasioned by the pandemic. The study identified some socioeconomic and institutional factors affecting the adoption of biofortified rice. Adopting biofortified rice could be a better strategy to increase farmers' income and productivity, as revealed by its significance across all income categories. The study, therefore, suggests that policy efforts should be geared towards improving the general living standards of the farmers so that they can afford the risks of trying out emerging technologies. One way this can be done is to enable financial institutions to create rural/farmer credit, and educational programmes for rice farmers since access to credit and information are positively associated with adopting the new technology. Alternatively, Farmers can be encouraged to form cooperatives and other farm organizations to enable them to solve some of their productivity issues using group dynamics and to share resources, skills, and experiences.

Furthermore, investigation suggests that the government is making substantial efforts to provide palliative measures for the farmers. However, the government's efforts barely reach the farmers due to the challenge of farmer herder conflicts and lack of access on the farmers' side. Government policies should be prioritized towards finding a lasting solution to the crop farmers-herders crisis by compelling the herders to embrace modern ranching techniques. Also, emergency agencies whose duties are to mitigate the effects of pandemic-related crises should have offices in the rural areas to enable them to have close contact with the rural farmers in times of emergency and information asymmetric.

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# COST-EFFECTIVE AND TIME SAVING METHOD OF PHENOLOGICAL MONITORING USING SATELLITE IMAGERY IN DRIP-IRRIGATED RICE

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***Abstract***

*Phenological monitoring is a necessary part of crop production. Fertilization, plant care measures, irrigation scheduling and plant protection are closely related in their efficiency to timely and precise determination of certain phenological phases of the cultivated plants to ensure the best out pay of the technological operations. Phenological observations are usually time-consuming and require some extra expenditures due to the need to visit each field of a farm or agricultural holding and cross it several times to assess the growth and development of the cultivated plants on the large scale. Modern technologies, mainly remote sensing, provide an opportunity to estimate crops development both on the scale of a local field or whole farm in time-saving and cost-effective manner through vegetation indices. The purpose of this study was to determine the correspondence between the values of the normalized difference vegetation index and phenological phases of drip irrigation rice, cultivated in the south of Ukraine during 2016-2017, to ensure the possibility of remote phenological monitoring in such crops. As a result, the highest values of the vegetation index were determined to be recorded in the tillering-heading period, and usually coincides with the period of July. The determined rice vegetation patterns are not only for rice growers due to time and cost savings for crop phenological monitoring, but are also of great importance for intelligent agriculture in the sense of crop recognition automation and mapping.*

***Key words*****:** *digital agriculture, normalized difference vegetation index, phenology, remote sensing, rice*

## INTRODUCTION

Phenological monitoring plays a crucial role in rational cultivation technology. Crop growth and development observations are necessary for efficient plant production management, playing a decisive role in fertilization, irrigation, plant protection scheduling, etc. In addition, it is of great scientific significance in the studies of crop reactions to various environmental conditions, technological operations, and in the studies related to the cycles of matter exchange in the biosphere [6].

Because agricultural activities and plant production are usually held in large spatial areas, which makes the conventional field observations time-consuming and costly, the need for finding cost-effective and time-saving alternative to in-field records is relevant to provide the highest possible profitability of plant production [3].

Integration of remote sensing into agriculture opens new opportunities for large-scale phenological monitoring.In this regard, normalized difference vegetation index recordings from satellite imagery are extremely helpful to provide a robust, precise, and easy-in-use tool for farmers to ensure timely and cost-saving control for the cultivated plants growth [4].

Previous studies, conducted in different regions for different crops, proved a high reliability of crop phenological monitoring through satellite data [12, 13]. Although the issue seems to be thoroughly studied, some areas remain *terra incognita* for modern digital agriculture. For example, the question of rice phenological monitoring using satellite imagery has been studied in numerous works; however, none of these studies was devoted to drip-irrigated rice, which can have absolutely different growth and development due to alternative environmental and cultivation conditions [2, 11, 17, 18, 20]. As far as rice is one of the most important food crops in the world, we are convinced that comprehensive study of its phenological monitoring is of a great relevance and significance to ensure food security in current conditions of global food guarantee problems [1].

Therefore, this study aims to determine the correspondence between the values of normalized difference vegetation index and drip-irrigated rice phenological phases. This is the first work to provide an annual pattern of the crop development in the conditions of drip irrigation in the relation to the spatial vegetation index for further use in crop mapping and automation monitoring systems of precision agriculture.

## MATERIALS AND METHODS

The study on drip-irrigated rice phenological monitoring using remote sensing data was conducted in 2016-2017 within the framework of the field experiment on its cultivation technology in the South of Ukraine, Kherson region.

The experiment embraced 96 variants randomly located in four replications within the square of the coordinates (provided as Google maps decimals):46.4724N, 33.1575E; 46.4706N, 33.1579E; 46.4711N, 33.1619E; 46.4729N, 33.1614E. The area of the plot was 125 $m^2$, while the experimental field total area was 1.2 ha.

Rice cultivar Flahman (var. *italic Alef*), included into the list of the State Register of Plant Varieties Suitable for Dissemination in Ukraine since 2009 [19], was used as a biological material in this study. Cultivation technology treatments embraced various tillage (discing at 10-12 cm; chisel plowing at 30-32 cm), fertilization ($N_0P_0$; $N_{90}P_{30}$; $N_{120}P_{45}$; $N_{150}P_{60}$), and watering rates under drip irrigation (starting with ETc adjusted from 120%, 140%, and 160%), although, these parameters are not the subject this study, they had some influence on rice growth patterns, resulting in changes in the crop phenology by the variants of the experiment. These discrepancies in the terms of phenological phases start were considered and smoothed in this study.

Most variants had similar phenological pattern regardless cultivation treatments, however, the unevenness in phenology that had been recorded in field surveys, were taken into account when finding the correspondence between NDVI values and stages of the crop growth. We recorded following phases of the crop growth and development, namely: Sowing-emergence; Emergence-tillering; Tillering-internode elongation; Internode elongation-heading; Heading-Maturity [8].

Remote sensing technique was applied to find the correspondence between drip-irrigated rice phenology and NDVI values. Satellite imagery was obtained at the free online platform for digital farming OneSoil AI, which uses combined Sentinel ½ screens with the resolution of 250 m to minimize possible distortions.

Table 1. Rice phenology and dates of NDVI imagery used for analysis in 2016 (the date with the highest NDVI is in bold)

| Phase | Calendar dates (field records) | NDVI dates (satellite records) |
|---|---|---|
| I. Sowing-emergence | 05/18-06/01 | 05/25 |
| II. Emergence-tillering | 06/01-06/23(26) | 06/04; 06/11; 06/14; 06/21; 06/24 |
| III. Tillering-internode elongation | 06/23(26)-07/13(17) | 07/01; 07/11; 07/14 |
| IV. Internode elongation-heading | 07/13(17)-08/12(20) | 07/21; 07/24; 07/31; 08/10; 08/20 |
| V. Heading-Maturity | 08/12(20)-09/30(10/11) | 09/20; 09/09; 09/12; 09/22; 10/09 |

Source: Own study.

The imagery on the platform is provided on the regular basis, however, we used cloud-free images only in our study that made the number of NDVI screens less than totally available. Each pixel of OneSoil NDVI image corresponds to the square of 5×5 m. Therefore, each experimental plot is represented by 5 pixels of OneSoil gridded screen. The correspondence between the plots in the field and gridded OneSoil image were manually established before accounting. The dates, when the NDVI images were taken and processed for each phenological phase of the crop within the time span of the study are presented in the Tables 1-2 for the year 2016 and 2017, respectively.

Mean values of NDVI index ± standard deviation wascalculated by the common statistical methodology in the Microsoft Excel 365 software [5].

The figures were created using standard diagrams toolkit included in Microsoft Excel 365.

Table 2. Rice phenology and dates of NDVI imagery used for analysis in 2017(the date with the highest NDVI is in bold)

| Phase | Calendar dates (field records) | NDVI dates (satellite records) |
|---|---|---|
| I. Sowing-emergence | 05/16-05/31 | 05/17; 05/30 |
| II. Emergence-tillering | 05/31-06/25(28) | 06/16; 06/19; 06/26 |
| III. Tillering-internode elongation | 06/25(28)-07/16(20) | 06/29; 07/01; 07/06; 07/11; 07/16 |
| IV. Internode elongation-heading | 07/16(20)-08/11(19) | 07/21; 07/24; 07/31; 08/03; 08/05; 08/08; 08/13; 08/18 |
| V. Heading-Maturity | 08/11(19)-09/29(10/10) | 08/20; 08/23; 08/25; 09/07; 09/09; 09/12; 09/14; 09/17; 09/27; 09/29; 10/04 |

Source: Own study.

## RESULTS AND DISCUSSIONS

As a result, average NDVI values for each phenological phase of rice were established, as well as mean monthly values.

It is interesting that average NDVI values for first two phases of rice growth and development are similar (Table 3). This fact makes it impossible to clearly distinguish between the phase of Sowing-emergence and Emergence-tillering when remotely controlling the crop growth. Therefore, unfortunately, it might be necessary at the beginning of the crop vegetation to visit fields and make visual surveys regarding rice phenology. Peak development of rice green biomass corresponds to the phases of Tillering-internode elongation and Internode elongation-heading, with further gradual senescence and drying of green biomass in pre-harvesting period.

Table 3. Correspondence between phenological phases of rice and average NDVI values for each stage, ± standard deviation

| Phase | NDVI value |
|---|---|
| Sowing-emergence | 0.29±0.15 |
| Emergence-tillering | 0.29±0.15 |
| Tillering-internode elongation | 0.56±0.10 |
| Internode elongation-heading | 0.53±0.17 |
| Heading-Maturity | 0.27±0.15 |

Source: Own study.

Successful rice phenology monitoring using MODIS NDVI data was also reported by other scientific groups [10, 14]. Besides, some authors also assume enhanced vegetation index (EVI) to be also feasible and prospective option for rice phenological monitoring, even though it is modestly presented in available free and commercial products for farmers [7, 16].

Yearly dynamics of NDVI presented in the Table 4 testifies about comparatively sufficient difference between the monthly values of the index, apart from the months of May and June representing the initial stages of the crop growth similarly to the mentioned above regularity. The established grades would be useful for identification of drip-irrigated rice in the systems of automatic crop mapping based on artificial intelligence and remote sensing data that is supported by previously conducted studies [9, 15].

Table 4. Mean monthly NDVI values on the drip-irrigated rice field, ± standard deviation

| Month | NDVI value |
|---|---|
| May | 0.29±0.15 |
| June | 0.31±0.16 |
| July | 0.64±0.11 |
| August | 0.40±0.17 |
| September | 0.29±0.17 |
| October | 0.16±0.01 |

Source: Own study.

For better understanding of the study results, it is essential to present a move of the vegetation index values through the growing season of the crop and on yearly scale through the diagrams.

Visual presentation of the crop growth dynamics depicted by NDVI values is provided in the Figures 1 and 2.

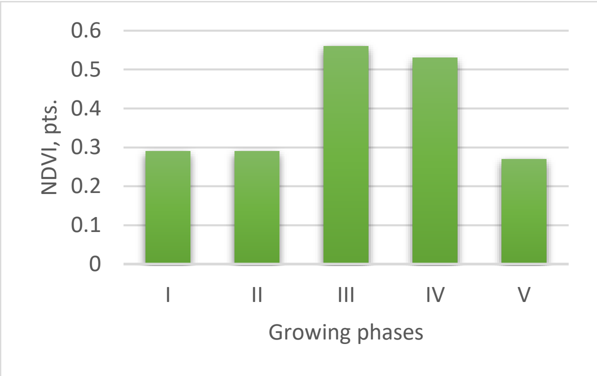


Fig. 1. Average NDVI values of the drip-irrigated rice by the phases of its growth

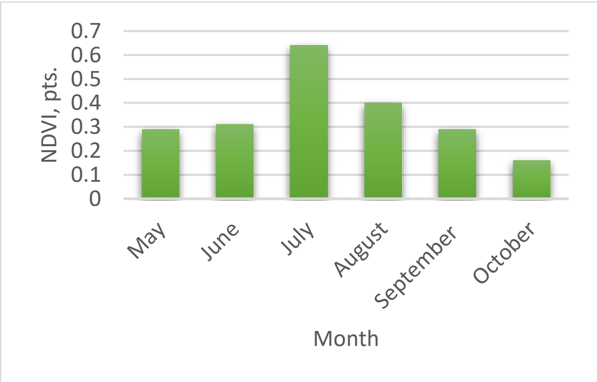


Fig. 2. Mean monthly NDVI values on the drip-irrigated rice field

Source: Own results.

## CONCLUSIONS

The results of the study revealed the patterns of NDVI move on the drip-irrigated rice field in the context of the crop's phenology and on yearly scale. It was proved that remote sensing NDVI data could be utilized for precise, cost-effective, and timesaving phenological monitoring of drip-irrigated rice. The only limitation relates to extremely slight difference between the beginning stages of the crop growth, namely, Sowing-emergence and Emergence-tillering. Yearly pattern could be further implemented in the systems of automatic crop mapping in the systems of precise digital agriculture.

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# PREDICTION OF CONDITIONAL VARIANCE VOLATILITY OF REAL PRICES OF ALMOND, HAZELNUT, AND PISTACHIO BY THE DIAGONAL BEKK-GARCH (1.1) EQUATION MODEL

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***Abstract***

*Turkey is one of the most important hazelnuts and pistachio producers in the world. In this study, it has been determined what kind of volatility and pass-through there is between the real prices of almonds, hazelnuts, and pistachios in Turkey. In addition, whether a shock in the markets creates uncertainty in its own market and other markets have been revealed. Diagonal-Bekk Garch (1,1) model was used under the Full-rank constraint with 192 monthly data sets between the period 2005M1-2020M12. The results of the research have put forth that the shocks that will occur in the almond market increase the uncertainty in its own market. Similarly, a shock in the hazelnut market increases the uncertainty both in its own market and in the pistachio market, while a shock in the pistachio market increases the uncertainty in its own market. Moreover, the shocks in the almond and hazelnut market are permanent in these markets in the short and long term, but the shocks in the pistachio market do not have a permanent effect in the short and long term.*

***Key words***: *price volatility, Diagonal-Bekk Garch (1,1) model, nuts industry*

## INTRODUCTION

The agricultural sector is the sector with the highest price volatility compared to other sectors. Agricultural price fluctuations create uncertainties for producers and consumers [20]. Although there are many reasons for the increases in agricultural product prices, they are the result of many factors that are interrelated [21]. Almond, hazelnut, and pistachio markets have an important position in the Turkish economy and are competitive product markets. While Turkey ranks first in hazelnut production and 3rd in pistachio production, it meets 1% of almond production in the world [18]. Possible developments in the dried nuts market also affect the markets of products that are substitutes for each other. The demand for the almond market has increased due to high increases in almond production, which is a substitute for pistachio, and less fluctuation in price compared to pistachio [17]. Turkey's foreign dependency on agricultural production is one of the most important problems in the agricultural sector. Excessive price volatility poses a threat to the future of the relevant markets. Despite global efforts and various controls, world food prices show a constantly rising trend for many years. Since the 2007-2008 food crisis, international organizations, governments, and non-governmental organizations have expressed their concerns about the increased volatility and fluctuations in food markets. Uncertainty in food prices, combating hunger and malnutrition, efforts to increase food production, and stabilizing consumer food prices are seen as the main problems. The fact that there are many parameters that affect the prices of agricultural products makes it difficult to calculate the effect of price volatility on producers and consumers [16]. As a matter of fact, there are important studies on agricultural product price volatility in the previous works. On the other hand, studies on price volatility between markets reveal that they have an effect on the interdependence of markets. In this regard, sudden and high increases in oil prices emerge as one of the most important problems. As a matter of fact, the effect of oil prices on the input costs of agricultural products is directly proportional to the size of agricultural food demand [9]. The increase in the input costs of petroleum and derivative products causes prices to rise and creates risks and uncertainty in the markets. Indeed, it was similarly determined that there is a volatility interaction between corn and wheat markets while another study reported that 24 agricultural product markets and oil prices between 1980 and 2010 affected agricultural commodity prices. [5, 13]. The volatility of sugar prices in Turkey was determined using monthly prices between 1994 and 2020 [15]. In the study, which draws attention to the commodity financialization of the level of interdependence between agricultural commodities (corn, wheat, soybean, and soybean oil) in 2017, it has been found that there is more spill over in the corn and wheat market. In particular, the soybean and soybean oil markets and surprising economic news have a strong impact on the volatility of agricultural commodities [10]. In the research examining the interaction between pistachio and exchange rate markets in 2016, it was observed that the pistachio market was directly and indirectly affected by the long-term uncertainty of other markets [3]. In a similar work, when the conditional variance volatility of the exchange rate of hazelnut and gasoline market prices is examined, it is concluded that the markets are affected both by their own short and long-term uncertainty and by the short and long-term uncertainty of other markets [4].

Therefore, the aim of this study is to analyze the volatility and pass-through in the real price returns of almonds, hazelnuts, and pistachios in Turkey, using the Diagonal BEKK GARCH (1,1) model with monthly data set for the period 2005:M1-2020M12. For this reason, first of all, empirical methods and data sets to be applied to the variables are introduced, empirical results are reported and policy recommendations are presented. Moreover, it has been revealed how the macro variables of the related markets are affected by the uncertainty in their variances in the face of negative or positive news. It has been quantitatively determined how the markets' own short and long-term uncertainties and how the uncertainties of the competitor's market reflect on the markets. With this research, it has been investigated how the almond, hazelnut, and pistachio markets in Turkey affect each other, and how the changes affect their own and other markets. With the results obtained from the study, policies have been determined on how to protect producers and consumers from price fluctuations that will occur in the future, in the face of negative or positive shocks that will mobilize the markets such as rising input costs.

## MATERIALS AND METHODS

### Data set

For almond, hazelnut, and pistachio prices, a data set was created using monthly 192 data from the Turkish Statistical Institute (TSI) for the period 2005M01-2020M12 [19]. The raw data of the three markets for the analysed period have been converted to real terms for analysis. The returns of the series are determined by the equation $R_{i,t} = \Delta \log(P_t) = 100 * \log(\frac{P_t}{P_{t-1}}), i = 1,2,3$.

In this equation, $P_t$ gives the current real prices of the relevant markets, while $P_{t-1}$ represents the prices of the previous period.

### Econometric Method

The financial time series of the relevant markets, which are the subject of the study, are generally macroeconomic variables with high volatility. An important feature of financial time series in the recent period is that they contain price volatility or varying variance (heteroscedasticity) over time. When the price volatilities in the time series of the three markets are analysed, high and low price volatility are examined from time to time. When it comes to volatility measurements in the markets, [6] developed the ARCH technique, which shows conditional variance. In multivariate models, the effect of shocks in the variables measures the effects that may occur both in their own markets and in the variances of other variables. Various approaches have been developed in order to measure the price volatility of such markets and to reveal the effects of shocks both in their own markets and in other markets, and one of them is explained with the Diagonal BEKK approach, which is discussed in the study.

The possible price volatility spread is evaluated with the diagonal BEKK approach [7]. In this study, Diagonal BEKK GARCH (1,1) method was preferred under Full Rank limitation to evaluate price volatility among almond, hazelnut, and pistachio markets.

Diagonal BEKK-GARCH is formulated as follows;

$$H_t = C^{''}C + B^{'}H_{t-1}B + A^{'}\varepsilon_{t-1}\varepsilon^{'}_{t-1}A$$

(1)

In this formula, C represents the constant matrix coefficients, while A, B represents the effect of short and long term shocks in the markets.

The matrix expansion in the BEKK approach is as follows [7]:

Assuming Ω is equal to an 3x3 matrix, C ′C,

$$= \begin{bmatrix} c_{11} & 0 & 0 \\ c_{12} & c_{22} & 0 \\ c_{13} & c_{23} & c_{33} \end{bmatrix} \begin{bmatrix} c_{11} & c_{12} & c_{13} \\ 0 & c_{22} & c_{23} \\ 0 & 0 & c_{33} \end{bmatrix} \qquad (2)$$

$$\begin{bmatrix} c^2 & c_{11}c_{12} & c_{11}c_{13} \\ c_{11}c_{12} & c_{12}^2c_{22}^2 & c_{12}c_{13}+c_{22}c_{23} \\ c_{11}c_{13} & c_{12}c_{13}+c_{22}c_{23} & c_{13}^2c_{23}^2c_{33} \end{bmatrix}$$

The Ht matrix is shown as follows;

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} \qquad (3)$$

The final state of the equation is expressed as:

$$H_t = \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} = \begin{bmatrix} \Omega_{11,t} & \Omega_{12,t} & \Omega_{13,t} \\ \Omega_{21,t} & \Omega_{22,t} & \Omega_{23,t} \\ \Omega_{31,t} & \Omega_{32,t} & \Omega_{33,t} \end{bmatrix}$$
$$+ \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix}^{'} \left( \begin{bmatrix} u_{1,t-1} \\ u_{2,t-1} \\ u_{3,t-1} \end{bmatrix} \begin{bmatrix} u_{1,t-1} \\ u_{2,t-1} \\ u_{3,t-1} \end{bmatrix}^{'} \right) \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix}$$
$$+ \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}^{'} \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix} \qquad (4)$$

In this context, each conditional variance and covariance equation is represented as:

$$h_{11,t} = \Omega_{11} + a_{11}^2u_{1,t-1}^2 + b_{11}^2h_{11,t-1} \qquad (5)$$

$$h_{12,t} = \Omega_{12} + a_{11}a_{12}u_{1,t-1}u_{1,t-1} + b_{11}b_{22}h_{12,t-1} \qquad (6)$$

$$h_{13,t} = \Omega_{13} + a_{11}a_{33}u_{1,t-1}u_{3,t-1} + b_{11}b_{33}h_{13,t-1} \qquad (7)$$

$$h_{22,t} = \Omega_{22} + a_{22}^2u_{2,t-1}^2 + b_{22}^2h_{22,t-1}$$

(8)

$$h_{23,t} = \Omega_{23} + a_{22}a_{33}u_{2,t-1}u_{3,t-1} + b_{22}b_{33}h_{23,t-1}$$

$$h_{33,t} = \Omega_{33} + a_{33}^2u_{3,t-1}^2 + b_{33}^2h_{33,t-1}$$

(9)

$$h_{33,t} = \Omega_{33} + a_{33}^2u_{3,t-1}^2 + b_{33}^2h_{33,t-1}$$

(10)

## RESULTS AND DISCUSSIONS

In the study, 192 monthly data sets for the period 2005M01-2020M12 were created and some analyses were carried out to investigate the effect of inter-market price volatility after the current prices were converted to real.

The descriptive statistics of the research findings are given in Table 1, the stationarity test of the series in Table 2, and the Diagonal BEKK-Garch (1,1) research findings of the series in Table 3.

In addition, other graphics that summarize the research findings are the price volatility of real prices over time in Figure 1, 2, and 3 and the combined price volatility of the price returns of the three markets over time in Figure 4.

Finally, variance, conditional variance and conditional correlation graphs are given in Figures 5 and 6, respectively.

Table 1. Descriptive statistics table of prices (TL/kg) of almonds, hazelnuts, pistachios*

| | r_almond | r_hazelnut | r_pistachio |
|---|---|---|---|
| Mean | 18.485 | 16.148 | 10.753 |
| Median | 16.277 | 11.750 | 8.810 |
| Maximum | 41.847 | 47.430 | 23.060 |
| Minimum | 11.637 | 6.180 | 4.390 |
| Standard deviation | 5.938 | 10.861 | 5.579 |
| Distortion | 1.676 | 1.273 | 0.586 |
| Kurtosis | 5.906 | 3.60 | 1.986 |
| Jarque-Bera | 157.555 | 54.853 | 19.238 |

Source: [19] *Calculated by author.

Table 1 presents the descriptive statistical results of the three markets that are the subject of the study. As a result of the monthly data of Almond, Hazelnut, and Pistachio for the period 2005M01-2020M12, the average price of almonds is 18.48₺, hazelnuts 16.14₺ and pistachios 10.75₺.

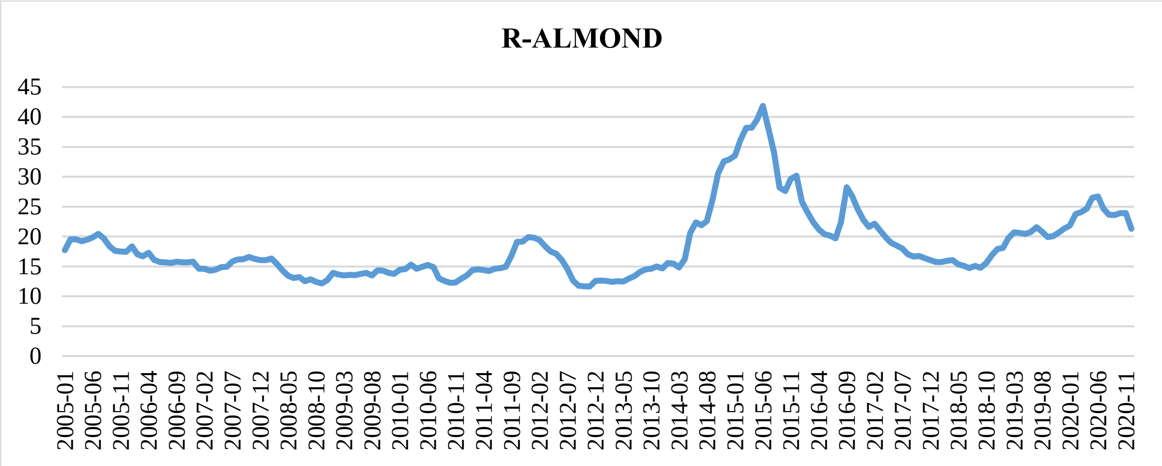


Fig. 1. Price volatility graph of real almond prices over time (TL/kg)
Source: [19].

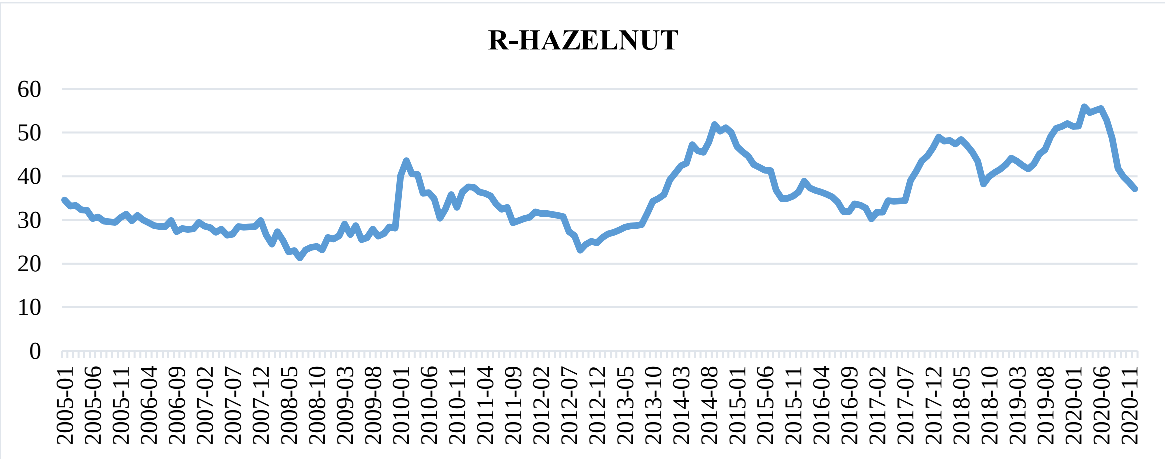


Fig. 2. Price volatility graph of real hazelnut prices over time (TL/kg)
Source: [19].

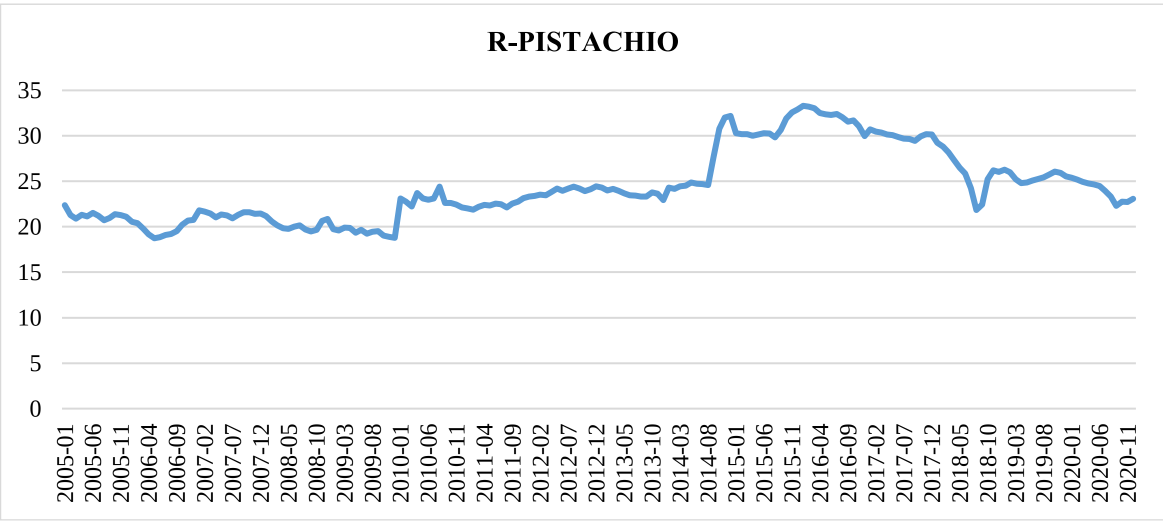


Fig. 3. Price volatility graph of real pistachio prices over time (TL/kg)
Source: [19].

When the maximum and minimum values were examined, the maximum values of the three markets were determined to be 41.84₺ for almonds, 47.43₺ for hazelnuts, and 23.06₺ for pistachios, respectively. distribution was not observed. In addition, the market price volatility clustering phenomenon clearly shows itself in the graphs of the return series in Figures 1, 2, and 3.

It is seen on the charts that there is price volatility in the markets. When Figure 1 is analysed in detail, the highest price volatility occurred between 2014-07 and 2016-07. The hazelnut market has a more active market than the almond market. While price volatility in the hazelnut market increased in 2010-01,2015-01,2018-01 and 2020-01, there was a decrease in prices in 2012-07 and 2017-01. Finally, when Figure 3 is observed in detail, it is noteworthy that the pistachio market exhibits less volatility than the other two markets, while the general level of prices in 2014-2015 increased, while there was a decrease in prices in the 2018-07 period.

Table 2. Results of the Stationarity Test of the Series*

| Dickey-Fuller (ADF) Test Statistic | | | | | | |
|---|---|---|---|---|---|---|
| | Extrinsic Variable: None | | Extrinsic Variable: Constant | | Exogenous Variable: Constant and Trend | |
| | t-statistic | possibility | t-statistic | possibility | t-statistic | possibility |
| r.almond | -8.821 | 0.000 | -8.795 | 0.000 | -8.769 | 0.000 |
| r.hazelnut | -11.872 | 0.000 | -11.842 | 0.000 | -11.809 | 0.000 |
| r.pistachio | -10.951 | 0.000 | -10.923 | 0.000 | -10.925 | 0.000 |

(1) The lag length for all series was chosen as 1 according to the Schwarz information criterion.
Source: *Calculated by author.

The results of the ADF unit root test applied for the series are given in Table 2. The series are based on constant and no-trend, only constant, and both constant and trend-containing regressions, respectively. As a result of the ADF tests, it was found that the series did not contain unit roots and were stationary.

In Table 3, under the BEKK-technique full rank constraint, the first three coefficients (C (1), C (2), and C (3)) show the long-term average of the respective markets. It shows the fluctuation caused by a shock that may occur in the variables, even if there is no variance and covariance effect. The first variable represents the almond market, the second variable represents the hazelnut market and the third variable represents the fresh pistachio market. Considering the average equation coefficients, the coefficients of all markets were found to be significant at the 1% significance level. First of all, a shock that may occur in the almond market causes fluctuations of 0.9% in the almond market, 1.7% in the hazelnut market, and 1.3% in the pistachio market, even if there is no variance and covariance pass-through. In a study, as a result of volatility transmission modelling on the determinants of agriculture, energy, and metal market risks in Brazil, it was found that US bond markets cause volatility in commodity markets [14]. In another study, which expresses the effect of volatility interaction between markets in the results obtained, the importance of the effect of interdependence between markets in the absence of a financial crisis is emphasized [8]. When the coefficients of variance equations are examined, C(4-15) ARCH and GARCH coefficients are C(4), C(7), C(8), C(9), C(10), C(11), C(12), C. (13), C(14) seems to be statistically significant (Table 3). The fact that the ARCH coefficients, which express the short-term uncertainty in the markets, are statistically significant, shows that the short-term shocks in the markets have a permanent effect. The fact that the coefficients giving the GARCH effect are statistically significant and at the same time the sum of the coefficients giving the ARCH and GARCH effect is greater than one, is an indication that shocks have a permanent effect in the short term and long term. Indeed, the correct determination of the relationship between the markets is very important for policymakers to make effective interventions on the spot [11].

The transformed coefficients of variance results are presented in Table 3. M from the covariance matrices shows the transition effect of the coefficient variables. M(1,1),M(2,2),M(2,3) and M(3,3) are statistically significant.

Table 3. Diagonal BEKK-GARCH (1,1) Analysis Results*

| System:SYS04 | | | | |
|---|---|---|---|---|
| Prediction Method: ARCH Maximum Likelihood (Marquardt) | | | | |
| Covariance Type: Diagonal BEKK | | | | |
| | Coefficient | Standard error | z-statistic | Probability |
| C (1) | 0.991698*** | 0.005960 | 166.3787 | 0.0000 |
| C (2) | 1.770028*** | 0.020101 | 88.05798 | 0.0000 |
| C (3) | 1.313004*** | 0.018341 | 71.58655 | 0.0000 |
| Coefficient of Variance Equation | | | | |
| C (4) | 0.265069*** | 0.039465 | 6.716500 | 0.0000 |
| C (5) | 0.381899 | 0.691665 | 0.552145 | 0.5808 |
| C (6) | 0.613862 | 0.450049 | 1.363990 | 0.1726 |
| C (7) | 2.036634*** | 0.197065 | 10.33486 | 0.0000 |
| C (8) | 1.494834*** | 0.227192 | 6.579592 | 0.0000 |
| C (9) | 0.702245*** | 0.193440 | 3.630305 | 0.0003 |
| C (10) | 0.537893*** | 0.077690 | 6.923615 | 0.0000 |
| C (11) | 1.026156*** | 0.106573 | 9.628642 | 0.0000 |
| C (12) | 0.921288*** | 0.095599 | 9.636986 | 0.0000 |
| C (13) | 0.864643*** | 0.021822 | 39.62248 | 0.0000 |
| C (14) | 0.277561*** | 0.071933 | 3.858579 | 0.0001 |
| C (15) | 0.211410 | 0.078662 | 2.687574 | 0.0072 |
| Log likelihood | -1252.785 | | | |
| Akaike info criterion | 13.27523 | | | |
| Hannan-Quinn criter | 13.37869 | | | |
| Schwarz criterion | 13.53065 | | | |
| Covariance Type: Diagonal BEKK | | | | |
| GARCH = M + A1*RESID(-1)*RESID(-1)'*A1 + B1*GARCH(-1)*B1 | | | | |
| M = full rank matrix, A1= diagonal matrix, B1= diagonal matrix | | | | |
| Converted Coefficients of Variance | | | | |
| | Coefficient | Standard error | z-statistic | Probability |
| M (1,1) | 0.068349*** | 0.020062 | 3.406876 | 0.0007 |
| M (1,2) | 0.145481 | 0.191009 | 0.761644 | 0.4463 |
| M (1,3) | 0.141000 | 0.108294 | 1.302011 | 0.1929 |
| M (2,2) | 4.200261*** | 0.628376 | 6.684314 | 0.0000 |
| M (2,3) | 3.039001*** | 0.475235 | 6.394728 | 0.0000 |
| M (3,3) | 2.848040*** | 0.441610 | 6.449213 | 0.0000 |
| A1(1,1) | 0.282782*** | 0.078512 | 3.601774 | 0.0003 |
| A1 (2,2) | 1.029064*** | 0.209830 | 4.904276 | 0.0000 |
| A1 (3,3) | 0.834776*** | 0.174932 | 4.772000 | 0.0000 |
| B1(1,1) | 0.751591*** | 0.035850 | 20.96511 | 0.0000 |
| B1 (2,2) | 0.076243** | 0.032903 | 2.317192 | 0.0205 |
| B1 (3,3) | 0.087944** | 0.039121 | 2.247986 | 0.0246 |

*, ** and *** indicate the significance level at 10%, 5% and 1%, respectively.
Source: *Calculated by author.

A shock in the almond market increases the uncertainty in its market (M(1,1) = 0.068). A shock in the hazelnut market increases both the uncertainty in its market (M(2,2) = 4.200) and the uncertainty in the pistachio market (M(2,3) = 3.039). One of the covariance matrices M(3,3), a shock in the pistachio market also increases the uncertainty in its market (M(3.3) = 0.087). Similarly, it has been found that the conditional variance of the hazelnut yield is directly affected by its long-term shocks [4]. A1 and B1 coefficients show the ARCH and GARCH effect, and A1 coefficients indicate whether the short-term shocks of the said markets have a permanent effect, and B1 indicates the effect of long-term shocks. In this context, the coefficients A1(1,1), A(2,2), and A(3,3) were found to be statistically significant. Therefore, it has been determined that the short-term shocks in the almond, hazelnut, and pistachio markets have a permanent effect. When the B1(1,1), B(2,2), and B(3,3) coefficients, which represent the persistence of long-term shocks, are examined in detail, the B(1,1) coefficient is statistically significant at the 1% significance level, B(2, 2) and B(3,3) were found to be statistically significant at the 5% significance level. On the other hand, when we look at the sum of the coefficients giving the ARCH and GARCH effect, it is seen that the ARCH and GARCH coefficients of the almond and hazelnut market (A1(1,1) + B1(1,1) =1,003), (A1(2,2)+B1(2,2)=1.09) indicates the persistence of short and long-term shocks that will occur in these two markets. However, the fact that the sum of ARCH and GARCH coefficients of the pistachio market (A1(3,3)+B1(3,3)=0.91) is less than one indicates that the shocks are not permanent for this market.

The price volatility of the returns of the almond, pistachio, and hazelnut markets over time is given in Figure 4. When the price volatility of the markets is analyzed simultaneously, a simultaneous increase was detected in the hazelnut and pistachio markets in 2010, while volatility was not determined in the almond market in the same year. While an increase was detected in the hazelnut and almond market in 2014, pistachio continued at the same level. Also, there was an increase in pistachio and almond prices in the 2015-01 period. While the excessive increase in almond prices was remarkable in 2016, it is noteworthy that the prices of hazelnut and pistachio remained at the same level.

Similarly, it was predicted that the effects of the slowdown in the economy would be felt relatively less in 2008 and 2009, but that agricultural prices would remain above the long-term averages [12]. The competitiveness of the product in international markets may also have an impact on price volatility. Indeed, the increase in export values and the decrease in the product supplied to the domestic market may also cause fluctuations in prices in the domestic market [1, 2].

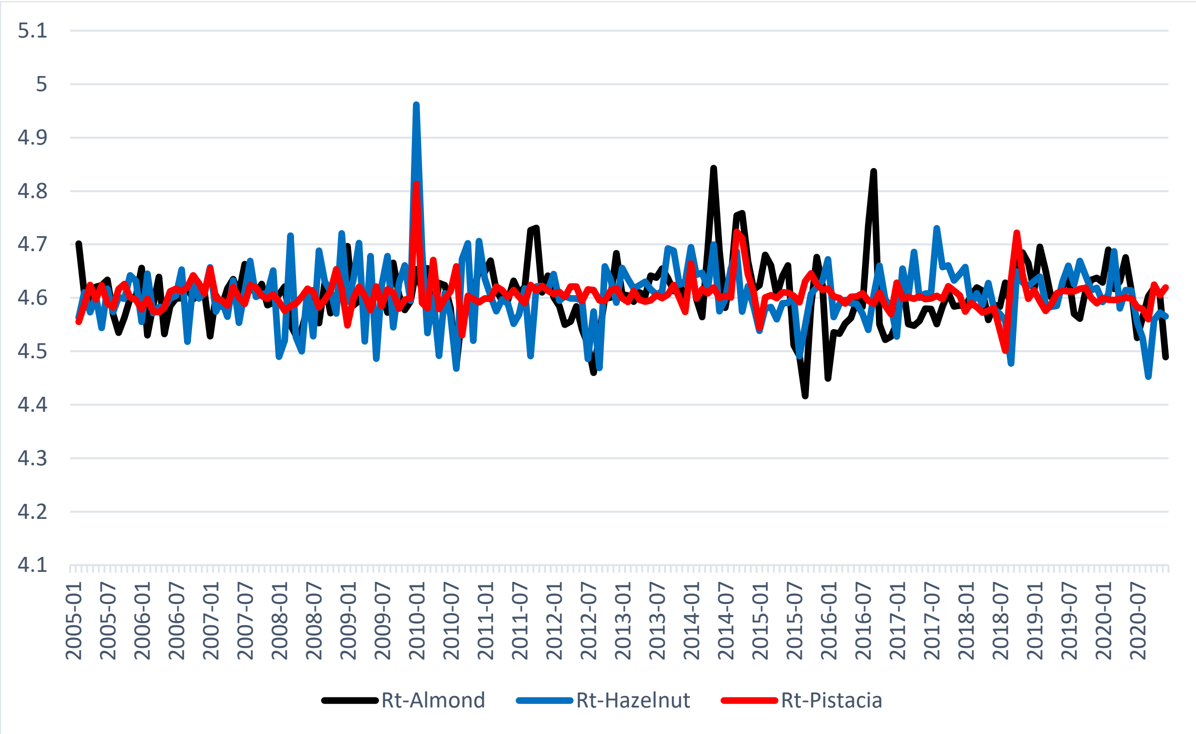


Fig. 4. Combined price volatility graph of yields over time (TL/month)*
Source: *Calculated by author.

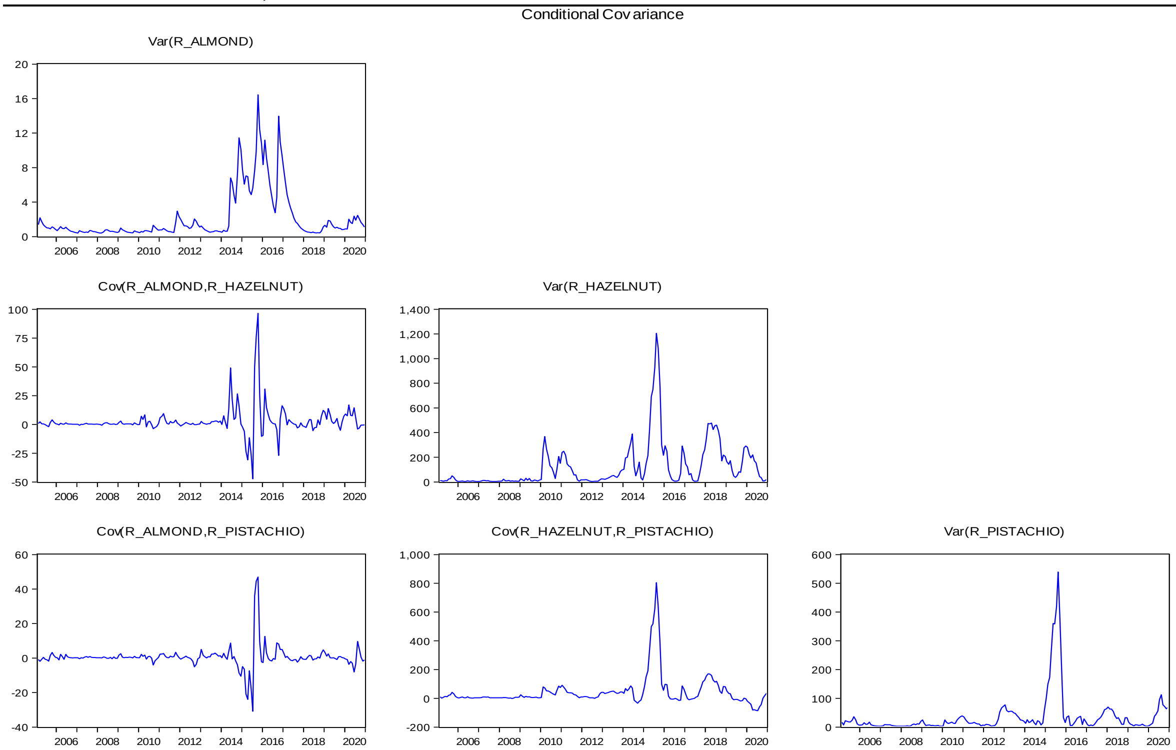


Fig. 5. Variance and conditional covariance graphs of data series*
Source: *Calculated by author.

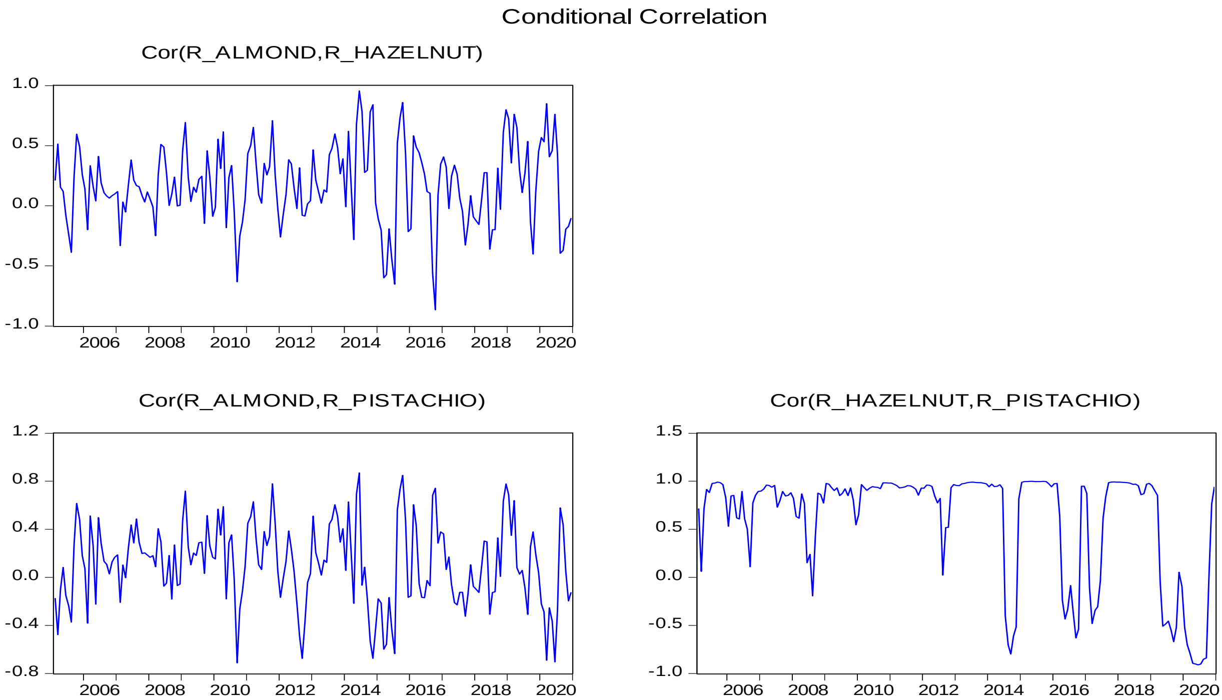


Fig. 6. Conditional correlation graphs of data series*
Source: *Calculated by author.

When the variance and conditional variance and conditional correlation graphs are examined, it is seen that the markets exhibited high volatility in 2010, 2014, 2015, 2016, and 2020 (Figures 5 and 6). This situation can be explained by the effect of the economic crisis in Turkey in the mentioned years. Beyond, the continuing effects of the world food crisis in 2010 and after, the economic crises, and the effects of the COVID-19 pandemic in 2019 affected the markets. The markets have negatively been affected by different factors such as climate change, drought, and the increase in input costs in recent years. These may be shown as a few of the reasons for price volatility in the markets.

## CONCLUSIONS

Price volatility in the almond, hazelnut and pistachio markets is clearly demonstrated using the Diagonal-Bekk Garch (1,1) model under the Full-rank constraint. Analysis results reveal that shocks in the almond market increase the uncertainty in its own market, while a shock in the hazelnut market increases the uncertainty both in its own market and in the pistachio market. In addition to these, it was revealed that a shock in the pistachio market increased the uncertainty in its own market. It has been determined that the shocks in the almond and hazelnut market are permanent in the short and long term, but the shocks in the pistachio market do not have a permanent effect in the short and long term. Agricultural price volatility and fluctuations in the markets in Turkey show parallelism with the world markets. There are many reasons for agricultural price fluctuations, such as the contraction in product supply due to the drought that has seriously affected the agricultural sector recently, and the increase in oil prices increasing the input costs in production. The necessity of creating a more stable market structure that will eliminate the uncertainties of these three markets, which have a significant share in the Turkish economy, is extremely important. It is recommended that policy makers responsible for the economy should primarily carry out studies that will increase productivity, improve marketing opportunities and ensure greater organization of the producer in order to eliminate price fluctuations. On the other hand, it is recommended both to implement policies for drought-resistant product diversification in order to prevent fluctuations in product supply caused by global climate change, and to monitor climate effects in the agricultural process for the sustainability of agricultural production. It is extremely important that policy makers provide support for producers with low income levels who will experience loss of real income as price fluctuations in the markets continue to be high in the medium and long term. Producers should be supported in order to guarantee production and reduce high price volatility. Finally, establishing strong systematic links between these markets will not only benefit the producers of the almond, hazelnut and pistachio markets, but also for national and international investors.

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# ASPECTS CONCERNING THE PRICE OF SOYA BEANS IN THE EUROPEAN UNION (2018-2020)

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***Abstract***

*Soya, is an important plant due to its plurivalence, taking into account aspects related to its use as an industrial raw material, from the point of view of its use in animal feed, as well as the agro-technical-technological aspects it covers. At the level of the European Union, for the period 2018-2020, soya was grown on an area of over 900,000 ha, generated a total production of about 2,800,000 tons and reached an average production level per unit of production (ha) of 2,996 kg (average of the period analysed). Starting from the physiological peculiarities of the plant, it is found that soya was practiced at the level of 15 states in the European Union. The main Community producers are represented by Italy, Romania and France (Italy – 1,078,270 tonnes respectively 38.42% of the Community total, Romania – 428,813.33 tonnes, share of 15.28% and France – 411,226.67 tonnes respectively 14.66%). In terms of performance per unit of production, Croatia, Greece, Italy, Slovenia and Spain stand out with levels above 3,000 kg/ha. The study presents the producer price situation ($/t). There is a multi-annual Community average of 381.36$/t, with extreme values of 307$/t for Romania (2020) and 566$/t for Spain (2019), and the total amplitude of variation recorded a level of 259$/t. At Community level, the evolution of the indicator is uneven, a phenomenon that is also manifested for the vast majority of the component states.*

***Key words*: *evolution, price, production, soybeans, variation***

## INTRODUCTION

Soybeans, is a crop plant with a considerable age (about 3,000 years), native to eastern Asia, which currently has a large range of varieties, being widely cultivated worldwide [11].
Soya is distinguished by a multiple processing at industrial level, this raw material generating products such as food oil, protein flour, protein concentrates, etc.Currently, soya, along with sunflower and rapeseed, is an oilseed crop successfully used in human diets [9]. Soy, can be used as a cheap source of protein in the human diet, its cost is lower than that of animal proteins [2]. Soybean oil can be used as a biofuel, influencing air quality by decreasing the degree of pollution [10]. In the fodder of different species of animals (swine, cattle, sheep) soya is used in various forms (ground, combined fodder, green mass, hay, silage, beanstalks and rinds).
From a technological point of view, it is worth mentioning the character of good forerunner (for a wide range of cultures), an aspect related to its belonging to the *Fabaceae* or *Leguminosae* family.
Soya is a cultivated plant also in the form of genetically modified organisms. From this point of view, however, Community policy is restrictive.As a result, the main growers worldwide are represented by the USA, Brazil, Argentina, Paraguay and Canada (89.9 million ha) [3]. Genetically modified soya may be of interest to production due to technological specificities [1].
Soya can be practiced, as a crop, also in an organic system, but at present, the cultivated areas are somewhat reduced [7].
At international level, we can also talk about an intense trade with soybeans, but for Romania, this article presents a deficient net trade balance [8].
In the case of the European Union, according to FAO data [4], we can say that soya is not a crop of particular importance, if we analyze the related area and the total production (about 900,000 ha and 2,800,000 t respectively).This aspect is determined by the

climatic conditions but also by the prices charged on the international market [6].

## MATERIALS AND METHODS

In order to prepare the paper, it was operated with the manufacturer price ($/t) for soybeans seeds, which is presented at UE and national level.The database consulted shall be that of the FAO. Prices in US dollars are equal to the producer's prices in local currency, which have been converted into dollars based on the exchange rate of the selected year [5]. The main source of the exchange rate used is the IMF.

The analysis refers to the period of time between 2018 and 2020, to which was added the average of the period, thus constituting a dynamic series consisting of 4 terms.

The analysis was carried out both at EU and national level (27 component states), presenting the positioning of each country in relation to the level of the average Community price, the absolute variations of the indicator (±$/t) and the dynamics of the indicator (%).There are no production dates for Belgium, Cyprus, Denmark, Estonia, Finland, Ireland, Latvia, Luxembourg, Malta, The Netherlands, Portugal and Sweden, and in the case of price there are no data for the above countries, but also for the Czech Republic, Greece, Italy, Lithuania and Poland.

The method of comparison in time and space and the method of percentages are used as analysis tools.

## RESULTS AND DISCUSSIONS

Table 1, contains the data related to the specific situation, in terms of price for soya - national and Community levels (under the conditions mentioned in the previous chapter - no data for Spain in 2020).

At the level of 2018, the average price at Community level was 399.70$/t, against which there were both supra-unit and sub-unit values at the level of the component countries. Thus, Austria and Spain are characterized by supra-unit levels: 405 and 566 $/t respectively. Sub-unit levels reached: 399 $/t in Slovakia and Hungary, 393 $/t for Bulgaria, 384 $/t each for France and Germany, 367 $/t for Slovenia, 358 $/t for Croatia and 342$/t for Romania.

The year 2019 is characterized by price variation limits from 307 $/t for Romania to 532$/t in the case of Spain. Consequently, we are talking about countries that recorded levels lower than the reporting base (community level of indicator – 360.70 $/t) - 352 $/t Austria, 333 $/t Bulgaria, 328 $/t Croatia, 343 $/t Slovakia, 329 $/t Slovenia and 357 $/t Hungary, but even higher - 364 $/t Germany.

Table 1. Price situation in the European Union ($/t)

| No. | Specification | Year | | | Period average** | |
|---|---|---|---|---|---|---|
| | | 2018* | 2019* | 2020* | Effective | % beside community level |
| 1 | Austria | 405 | 352 | 389 | 382.00 | 100.17 |
| 2 | Bulgaria | 393 | 333 | 390 | 372.00 | 97.55 |
| 3 | Croatia | 358 | 328 | 384 | 356.67 | 93.53 |
| 4 | France | 384 | 362 | 398 | 381.33 | 99.99 |
| 5 | Germany | 384 | 364 | 404 | 384.00 | 100.69 |
| 6 | Romania | 342 | 307 | 349 | 332.67 | 87.23 |
| 7 | Slovakia | 399 | 343 | 373 | 371.67 | 97.46 |
| 8 | Slovenia | 367 | 329 | 367 | 354.33 | 92.91 |
| 9 | Spain | 566 | 532 | *** | 549.00 | 143.96 |
| 10 | Hungary | 399 | 357 | 399 | 385.00 | 100.95 |
| 11 | Community level | 399.70 | 360.70 | 383.67 | 381.36 | 100 |

Source: *http://www.fao.org/faostat/fr/#data/PP(03.03.2022).
** own calculation;***missing data.

If we refer to the specific situation of 2020, we find a Community price of 383.67 $/t, against which the component states have positioned themselves as presented in Table 1.

As we may see from Table 1, overshoots were registered by Germany – 404 $/t, Hungary – 399 $/t, France – 398 $/t, Bulgaria – 390 $/t, Austria – 389 $/t, Croatia – 384 $/t, and decreases by Romania – 349 $/t, Slovakia – 373 $/t, Slovenia – 367 $/t.

Based on the annual statements presented above, the average of the period characterized by a Community level of the indicator of 381.36 $/t was determined.Compared to this state of affairs, the component states were positioned as follows: sub-unitary levels: 99.99% France – 381.33 $/t, 97.55% Bulgaria – 372 $/t, 97.46% Slovakia – 371.67 $/t, 93.53% Croatia – 356.67 $/t, 92.91% Slovenia – 354.33 $/t, 87.23% Romania – 332.67 $/t (Fig. 1); supra unit levels: 100.17% Austria – 382 $/t, 100.69% Germany – 384 $/t, 100.95% Hungary – 385$/t, 143.96% Spain – 549 $/t (Fig. 2).

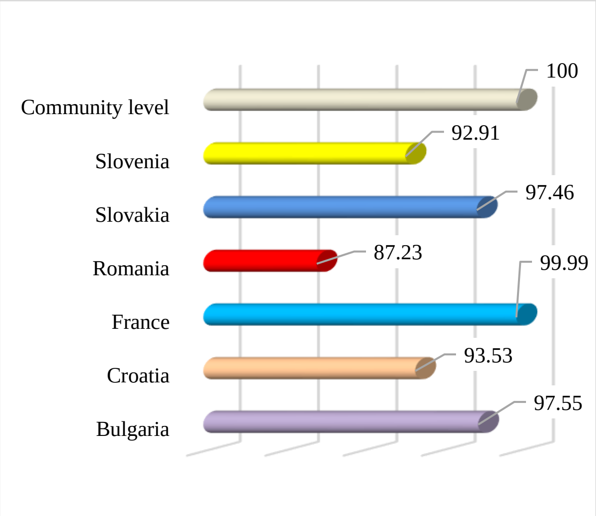


Fig. 1. Positioning of states with prices below the Community average level (%)
Source: own calculation.

Table 2 shows the absolute price variation ($/t) at the level of the component states of the European Union, as well as at the level of the Region. For Austria, there are increases for 2020 compared to the reporting base (+37.0 $/t), but also decreases in 2019 and for the period average (-53.0 and -7.0 $/t, respectively).

Bulgaria, is characterized by the existence of two situations when the indicator decreases, compared to the reference term – 2019 and the average of the period (-60.0 and -18.0 $/t) and by a situation of increase in the indicator level – year 2020 (+57.0 $/t).

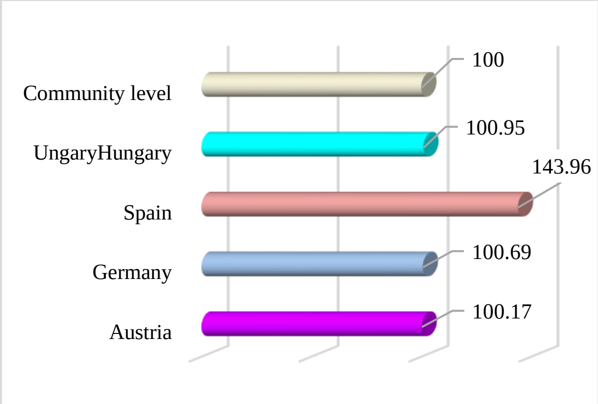


Fig. 2. Positioning of states with prices above the Community average level (%)
Source: own calculation.

Table 2. The absolute price variation * (±$/t)

| No. | Specification | ±Δ 2019vs. 2018 | ±Δ 2020 vs. 2019 | ±Δ media vs. 2020 |
|---|---|---|---|---|
| 1 | Austria | -53.0 | +37.0 | -7.0 |
| 2 | Bulgaria | -60.0 | +57.0 | -18.0 |
| 3 | Croatia | -30.0 | +56.0 | -27.33 |
| 4 | France | -22.0 | +36.0 | -16.67 |
| 5 | Germany | -20.0 | +40.0 | -20.0 |
| 6 | Romania | -35.0 | +42.0 | -16.33 |
| 7 | Slovakia | -56.0 | +30.0 | -1.33 |
| 8 | Slovenia | -38.0 | +38.0 | -12.67 |
| 9 | Spain | -34.0 | - | - |
| 10 | Hungary | -42.0 | +42.0 | -14.0 |
| 11 | Community level | -39.0 | +22.97 | -2.31 |

Source: *own calculation.

In the case of Croatia, there is a trend of increasing the level of the indicator in 2020 (+56.0 $/t) as well as two downward trends in 2019 and for the average period(-30.0 and -27.33 $/t, respectively).

In the case of France, it is found that the indicator showed two downward trends (-22.0 and -16.67 $/t for 2019 and for the period average, respectively) and an upward trend for 2020 (+36.0 $/t).

Germany is characterized by the existence of a situation when the indicator increases, compared to the reference period – year 2020 (+40.0 $/t) and by two situations of decrease in the level of the indicator – the year 2019 and the average of the period (20.0 $/t each).

In the case of Romania, there are two downward trends in the level of the indicator

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for 2019 and for the average of the period (-35.0 and -16.33 $/t, respectively) as well as an upward trend in the case of 2020 (+42.0 $/t) respectively.

Slovakia shows downward trends for 2019 and the average period (-56.0 and -1.33$/t, respectively), as well as an upward trend for 2020 (+30.0 $/t).

For Slovenia, the price decreased -compared to the reporting base- by 38.0 $/t in 2019 and by 12.67 $/t for the average period, and increased in 2020 compared to 2019 by 38.0 $/t.

Spain shows a decrease of 34.0$/t in 2019 compared to 2018.

In the case of Hungary, it is found that the indicator showed an upward trend for 2020 (+42.0 $/t) and two decreasing trends for 2019 and for the average period (-42.0 and -14.0 $/t).

At community level, the price fluctuation is observed, the negative differences characterizing the year 2019 and the average period (-39.0 and -2.31 $/t, respectively), and in the case of 2020 there is an increasing level of the indicator compared to the reference term (+22.97 $/t – Fig. 3).

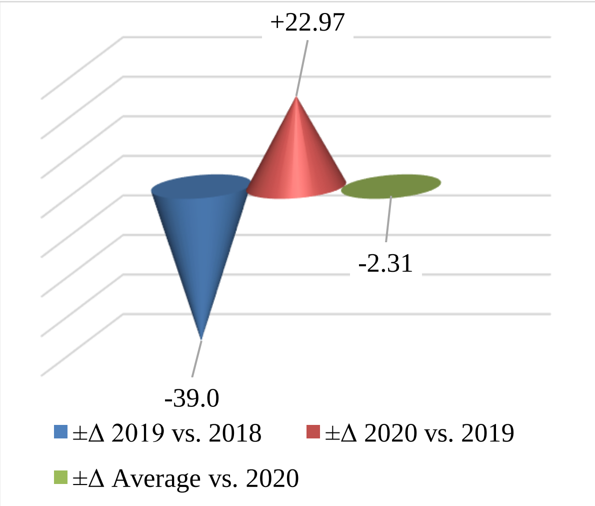


Fig. 3. Absolute change in the community average price ($/t)
Source: own calculation.

The marketing price recorded a multi-annual Community average of 381.36$/t, with extreme values of 307$/t for Romania (2020) and 566$/t for Spain (2019), and the total amplitude of variation recorded a level of 259.0$/t.

As for the indicator's annual variation amplitudes, they were 224.0$/t in 2018, 225.0$/t in 2019, 55.0$/t for 2020 and 216.33$/t for the period average (Fig. 4).

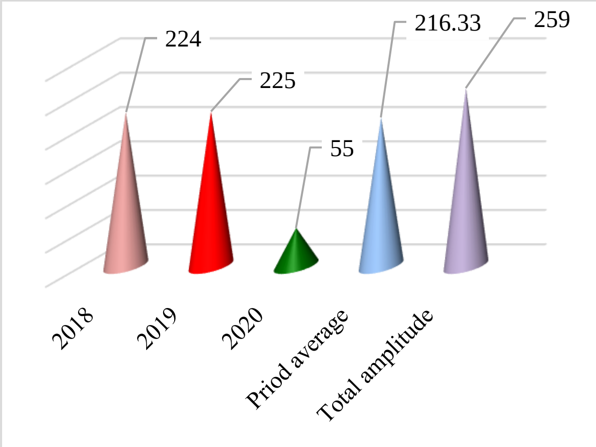


Fig. 4. Total and annual amplitude of price change ($/t)
Source: own calculation.

If we analyse the indicator below the ratio of the variation amplitude for each reference level (national and Community), the changes are shown in Fig. 5.

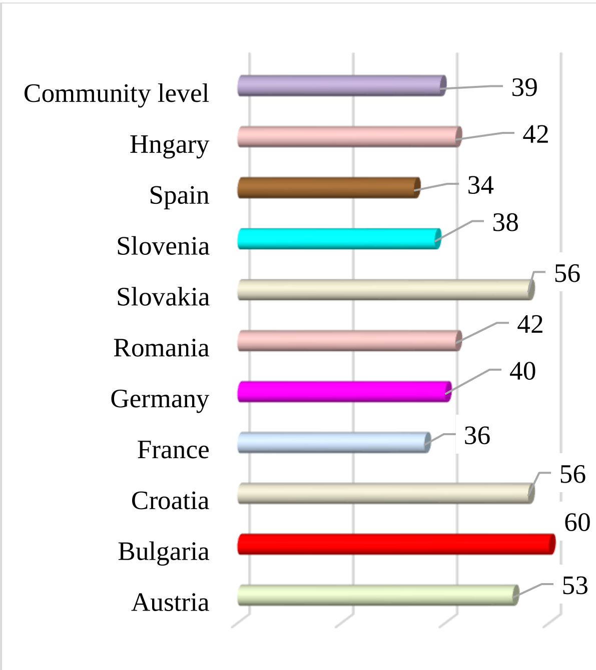


Fig. 5. Amplitude of price variation, at national and community level ($/t)
Source: own calculation.

From Fig. 5, we may see: 34.0 $/t in Spain; 36.0 $/t in France; 38.0 $/t for Slovenia; 39.0 $/t at European Union level; 40.0 $/t in Germany; 42.0 $/t each for Romania and Hungary; 53.0 $/t in the case of Austria; 56.0

$/t each for Croatia and Slovakia; 60.0 $/t at the level of Bulgaria.

Table 3 shows the price dynamics at communityand national level.

Table 3. Purchase price dynamics (%), at community and national level*

| No. | Specification | Year | | | | | | Period average | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2018 | | 2019 | | 2020 | | | |
| | | Mbi | Fbi | Mbi | Fbi | Mbi | Fbi | Mbi | Fbi |
| 1 | Austria | 100 | 100 | 86.91 | 86.91 | 96.05 | 110.51 | 94.32 | 98.20 |
| 2 | Bulgaria | 100 | 100 | 84.73 | 84.73 | 99.24 | 117.12 | 94.66 | 95.38 |
| 3 | Croatia | 100 | 100 | 91.62 | 91.62 | 107.26 | 117.07 | 99.63 | 92.88 |
| 4 | France | 100 | 100 | 94,27 | 94,27 | 103.65 | 109.94 | 99.30 | 95.81 |
| 5 | Germany | 100 | 100 | 94.79 | 94.79 | 105.21 | 110.99 | 100.0 | 95.05 |
| 6 | Romania | 100 | 100 | 89.77 | 89.77 | 102.05 | 113.68 | 97.27 | 95.32 |
| 7 | Slovakia | 100 | 100 | 85.96 | 85.96 | 93.48 | 108.75 | 93.15 | 99.64 |
| 8 | Slovenia | 100 | 100 | 89.65 | 89.65 | 100.0 | 111.55 | 96.55 | 96.55 |
| 9 | Spain | 100 | 100 | 93.99 | 93.99 | - | - | 96.99 | - |
| 10 | Hungary | 100 | 100 | 89.47 | 89.47 | 100.0 | 111.76 | 96.49 | 96.49 |
| 11 | Community level | 100 | 100 | 90.24 | 90.24 | 95.99 | 106.37 | 95.41 | 99.40 |

Source: *own calculation.

Austria shows a fluctuating evolution – over time. The fixed base indices range from 86.91% for 2019 to 96.05% in 2020. At the level of the indices with the mobile base, the limits of variation were of 86.91 and 110.51% in the case of 2019 and 2020, respectively,

Bulgaria shows an uneven development of the indicator. As a result, the price decreases in 2019 compared to 2018 by 15.27%, its increase in 2020 compared to the second reference term (+17.12%). The average period is lower compared to both reporting bases (-5.34 and -4.62%).

Croatia's situation is customized by the fact that there are decreases in 2019 compared to 2018 (8.38%), and in the case of 2020 there are increases of 7.26 and 17.07% compared to the terms of reference. The average period is lower by 0.37 and 7.12% compared to the reporting bases.

In the case of France, the indicator decreases in 2019 by 5.73% compared to the first term of the dynamic series, then in 2020 there are increases (+3.65% compared to the first term of the dynamic series and +9.94% compared to the previous year), and the average is lower by 0.70 and 4.19% respectively compared to the specific situation of the years 2018 and 2020.

If we refer to the specific situation of Germany, it is found that the first reporting base is exceeded only in 2020 (+5.21%). As for the indices with the mobile base, they are subunits for 2019 and for the average period (94.79 and 95.05% respectively). It is worth noting the similarity between the levels of 2019 and the average of the period.

For Romania, the evolution trend is fluctuating (decrease in 2019 compared to 2018 by 10.23%, increases in 2020 by 2.05 and 13.68% compared to the terms of reference). In the case of the average period, the indices are subunits – 97.27 and 95.32% respectively.

Slovakia is similarly to that of most of the countries presented so far. Thus, there are decreases compared to the terms of comparison by 14.04% in 2019, 6.52% in 2020 and by 6.85% for the average period (compared to 2018), but also their exceedances by 8.75% in 2020 compared to the previous year of the dynamic series.

Slovenia is characterized by the existence of a single supra-unit value, of the dynamics indices, in 2020 (111.55% - indices with the mobile base), equal for the same year (compared to 2018), respectively the subunit in 2019 (89.65%) and for the average of the period (96.55%).

In the case of Spain, the indicator decreases in 2019 by 6.01% compared to the first term of the dynamic series, then the average decreases by 3.01% compared to the specific situation of 2018.

Hungary has supra-unit values of the indices in dynamics in 2020 (111.76% compared to the previous year), equi unit values for the same year compared to the situation in 2018, respectively subunit in 2019 (89.47%) and for the average period (96.49%).

At Community level, the dynamics of the indicator contains supra-unit values only for 2020 (1.06% advance of the situation in 2019), and in the rest appear sub-unit values, as follows: 90.24% for 2019, 95.99% in 2020 compared to the first term of the dynamic series, 95.41 and 99.40% for the average period of the period.

## CONCLUSIONS

At Community level, price developments are uneven, a phenomenon which is also manifested for the vast majority of states (Austria, Bulgaria, Croatia, France, Germany, Romania and Slovakia). There are other trends such as a downward one for Spain, as well as some fluctuating ones with stabilization trends for Slovenia and Hungary.

The price is influenced by the supply-demand ratio, and it can also be influenced by other factors: the "strategic" character of the product, the intervention of the economic actors within the chain, the way of managing the stocks, etc.

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# MATHEMATICAL MODEL FOR ESTIMATION OF THE DIGITALIZATION OF THE PRODUCTION STRUCTURE IN ANIMAL HUSBANDRY

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***Abstract***

*A mathematical model was tested to assess the digitization of stock farms in various sub-sectors of animal husbandry from the region of southwestern Bulgaria. In the assessment of the farm, only the software and hardware devices used by the persons employed in the respective farm were taken into account. The farms consisted of 5 departments located in a hierarchical structure on 4 levels. The results showed a relatively low degree of digitization of the surveyed farms. Comparisons were made for effective transfer and use of incoming information within each department of the surveyed farms. A unified 20-digit code is proposed for use to estimate the degree of digitization.*

***Key words:*** *digitalization, animal husbandry, mathematical model*

## INTRODUCTION

One of the major challenges in the modern world is how to ensure food security for the growing population while at the same time providing long-term sustainable development. According to the Food and Agriculture Organization [2], agricultural and food production must increase to feed the world's population, which will reach about 10 billion by 2050. Due to the imposition of ever higher standards for the quantity and quality of food products, the issue of food security, sustainability, productivity and profitability is becoming increasingly important. Digitization can help address feeding the growing world population while mitigating the negative environmental and climate impacts of industrial agriculture [6].

Given that the impact of human activity leads to massive environmental pollution, digitization in the food industry is becoming a necessity [3]. The benefits of using the digital technologies are known to farmers and may include higher animal productivity, optimization of production factors, reduction of labour, digitization of the processing a large set of data, improvement of working conditions and reduction of the negative impact of agriculture on the environment [1].

The introduction of computers led to increasingly automated processes, reducing the need for some manual activities. In this case, scholars refer to digitization as the third industrial revolution [4], which affects the business level in using technology. Digitalization has affected agricultural and food production systems and is making possible the application of technology and advanced data processing techniques in agriculture [7]. However, the agricultural sector is complex, dynamic and requires sophisticated management systems. The wider application of digitalization is expected to provide more optimization of production and management processes and as well as additional assistance in making the right decisions [12].

In the last two decades, the marketers of the large corporations have taken up the task of getting feedback from how new technologies enter people's lives and what are the reasons why they enter some spheres of people's lives, while in others they do not find application at

all. This was mainly carried out by consulting companies through individual analysis of firms using a variety of approaches [13].
Currently, there is no single unified method for assessing the degree of digitization in farms [11].
The results from such research were not satisfactory. Hence, in recent years the summarizing of the disparate information from different companies in a common evaluation methodology has been discussed. However, the latter should be based not on methods such as gap or swot analyses but on the assessment of the degree of entering of the IT technologies and software solutions in the respective farm [9, 14, 10]. The latter are the main factor on which every digitization process is based. There are similar examples in assessment the entering of digital solutions in management of the information from the ports [5, 15]. In our opinion, the individual structures of the farm stand out in the foreground in the assessment, as being responsible for different production activities. From our previous studies, we can note that one of the departments where all new solutions, including the digitization of information, are the easiest to enter are the marketing and administrative departments [10]. The need for digitization is evident for every level in all departments of the farm, due to the requirement for continuous transfer of data between them in order to manage more effectively and make quick decisions when critical situations arise.
The objective of our study was to test a version of a uniform rating system for farms in the field of animal husbandry, to be applied to summarize the information from questionnaire surveys. We used a coding that can be processed at a later stage by using a methodology to evaluate the group of farms in some sub-sectors of animal husbandry.

## MATERIALS AND METHODS

Mathematical and statistical functions of the Microsoft Office Excel package were used to estimate the digitization of the farm and to present the results. Where necessary, logical operators were also used.
The structure of a stock farm, as in most other enterprises, generally included 5 departments that perform different independent functions (logistics, consulting, production, administration and sales). When preparing the model, a four-level hierarchical pyramid proposed by O'Brein and Marakas [8] was used. It arranged the hierarchical structure in each enterprise in 4 levels, with the 4$^{th}$ level being the lowest in the structure and those working in it have direct contact with the sources of information. They were responsible for its introduction into the system. These were the ordinary workers performing operations in each of the main departments of the enterprise. At the 3$^{d}$ level of the hierarchical structure, employees were responsible for the correct progress of the production processes and/or in any of the other departments of the enterprise. The 2$^{nd}$ level of the pyramid included the so-called subordinate managers responsible for a separate group of activities in the relevant sector of production. The managers managing and handling the information of each of the departments were at the first level It is possible that in smaller enterprises the hierarchical structure is not preserved in its classical form, and the hierarchy of a given department may be reduced from 4 to 3, 2 or 1 level, due to lack of sufficient staff or in order to redirect the existing staff to other departments. The full hierarchical structure is most often seen in large corporations. In small enterprises, a lack of hierarchical structure is very often observed, therefore it is assumed that one person performs all the activities typical for one of the 5 departments of the enterprise.
In this study, we assumed that the existence of each of the departments of the stock farm was mandatory, since every single company, regardless of the number of employees, performs the activities typical for each of the above-mentioned departments. We accepted that in developing of the coding, the absence of a hierarchical structure was permissible, contrary to the absence of any of the 5 departments. The evaluation model was based on our previous research [10] and represented the positioning of each of the evaluated cells

according to the software and hardware applications that it actively uses in one of the 9 degrees of digitalization that we have proposed. The degrees of digitization were coded as follows (Table 1).

Table 1. Evaluation table for degrees of digitization of information and their code

| N | Degree of digitalisation | Numeric code |
|---|---|---|
| - | Absence of unit | X |
| 0 | Lack of digitalization | 0 |
| 1 | Availability of specialized simplified software for data processing and storage | 1 |
| 2 | Data transfer by using the capacities of the Internet | 2 |
| 3 | Use of passive internet based solutions | 3 |
| 4 | Use of active internet based solutions | 4 |
| 5 | Use of cloud based software solutions | 5 |
| 6 | Full automatization and digitalization at the 4th level | 6 |
| 7 | Absence of control fuctions of the subjective factor on the 3d and 4$^{th}$ level | 7 |
| 8 | Absence of control functions of the subjective factor on 2$^{nd}$ to 4$^{th}$ level | 8 |
| 9 | Absence of control functions of the subjective factor on 1$^{st}$ to 4$^{th}$ level | 9 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The higher level in the hierarchy also requires a higher degree of digitization. We set requirements for maximum digitization at the top level in the hierarchical structure, with each subsequent lower level the degree of digitization decreases by one.

The digitization model that we propose can be represented as a matrix with 4 rows and 5 columns, with the coefficient in each cell in the matrix representing the degree of digitization for the corresponding level and department. The maximum score on the 9-point scale is 9 for the first level (all coefficients from a1 to a5 of the first row), respectively 8 for the second level (coefficients from b1 to b5), 7 for the third level (coefficients from c1 to c5) and 6 for the fourth lowest level (coefficients d1 to d5) as shown in Figure 1.

$$\begin{pmatrix} a1 & a2 & a3 & a4 & a5 \\ b1 & b2 & b3 & b4 & b5 \\ c1 & c2 & c3 & c4 & c5 \\ d1 & d2 & d3 & d4 & d5 \end{pmatrix}$$

Fig. 1. Model of digitization of the stock farm
Source: Authors' original model for evaluation of the digitalization in the studied farm.

The assessment of the degree of digitization of the farm that we propose was done in 2 stages. In the first, the degree of digitization of the farm as a whole was assessed and calculated as percent of the maximum possible degree of digitization, which is 100%. In the second stage, we indicated departments whose activity was not efficient enough and required restructure. These were levels of departments whose degree of digitization was lower than those down in the hierarchical structure of the farm.

**Stage 1**

In the model that we propose, the degree of digitization was presented in %, with each of the departments at each level in the stock farm (respectively, each of the coefficients in (1) participating with an equal share and was % of the maximum possible digitalization estimate for the respective level. We postulated that each farm had 5 departments with 4 levels. Since the farms have different degrees of output volume, it is quite possible, especially for smaller enterprises, that some of the hierarchical levels are missing, as well as some of its departments or functions have been taken over by other departments. We have tried that the lack of departments does not affect the degree of digitization of the farm. For example, if the presented model is missing 6 of the departments out of the possible maximum of 20 departments for all 4 levels, the degree of digitization will be assessed only for the existing 20 – 6 = 14. Mathematically this can be expressed as follows:

$S = \frac{100}{f} \times \sum_{g=1}^{f} K_g$ ................................(1)

where:
-S is the degree of digitization of the entire model (%),
-K is the level of digitization of each level,
-f is the number of levels that are digitized.
The detailed equation is:

$$S = \frac{100}{f}\left(\sum_{i=1}^{n}\frac{a_1+\cdots+a_n}{a_{max}\times n} + \sum_{i=1}^{l}\frac{b_1+\cdots+b_l}{b_{max}\times l} + \sum_{i=1}^{m}\frac{c_1+\cdots+c_m}{c_{max}\times m} + \sum_{i=1}^{p}\frac{d_1+\cdots+d_p}{d_{max}\times p}\right) \quad (2)$$

....................................................................(2)

where:
-S is the degree of digitization of the entire model (5),
-K is the degree of digitization of each level,
-f is the number of levels that are digitized, the coefficients a,b,c, and
-d are the degrees of digitization for the corresponding levels and departments;
-$a_{max}$, $b_{max}$, $c_{max}$ and $d_{max}$ are the maximum possible degree of digitization for the corresponding levels,
-n, l, m and p are the existing number of departments in the farm for each of the levels.
An example for the estimation of the degree of digitization for a stock farm/enterprise is shown in Table 2. The numerical value is an estimate of the corresponding degree of digitization. The letter X means that the relevant department does not exist as a structure in the enterprise. The last cell at the bottom right is the final score for the degree of digitization for the entire farm.

Table 2. Example of estimation of the digitalization level in a farm/enterprise

| **Level** | **Department** | | | | | **Mean for the level** |
|---|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales | |
| 1 Level | 9 | 4 | 7 | X | 7 | 75.00% |
| 2 Level | X | 5 | 3 | 4 | 3 | 46.88% |
| 3 Level | 6 | 6 | 5 | 7 | 4 | 80.00% |
| 4 Level | 5 | 2 | 1 | 2 | 1 | 36.67% |
| Mean for each department | 89.68% | 56.50% | 50.84% | 61.11% | 47.27% | 59.64% |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

**Stage 2**

Table 3 shows the differences in the degrees of digitization of the departments of the farm hierarchical structure.

Comparisons are made of the degrees of digitization between every 2 adjacent levels for each of the departments in the operation (the results from Table 2 are used).

In case the structural unit of the next lower level is missing in the farm, a comparison is made with the next level.

Negative estimation means that the corresponding level for this department is not used effectively and needs to increase the degree of digitalization.

The letter x means that the either the department or the levels in the department that are lower are missing in structure and no comparison is possible.

The digitization evaluation code of the enterprise is a series of the evaluations of the level of digitization of each of the departments, starting from the highest level to the lowest level of the enterprise (the values in Table 2 from the first to the fifth column).

The code for the evaluation of the digitalization of the farm is a series of the evaluations of the level of digitization of each of the departments, starting from the highest to the lowest level of the farm.

This involves the values in Table 2 from the 1st to the 5th column, and hence, the code is “9X65-4562-7351-X472-7341“.

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Table 3. Example of the efficiency estimation of the respective departments in the stock farm

| Differences in levels | Departments | | | | |
|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales |
| 1- next level | 3 | -1 | 4 | x | 4 |
| 2- next level | x | -1 | -2 | -3 | -1 |
| 3- next level | 1 | 4 | 4 | 5 | 3 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

## RESULTS AND DISCUSSIONS

The model we developed was used to assess poultry, sheep, cattle and pig farms in the region of southwestern Bulgaria. This is a private case of a stock farm breeding various species of animals from the region of Sandanski municipality. In the assessment of the farm, only the software and hardware devices used by the employees for the performance of their official duties were taken into account.

**Assessment of the degree of digitalization in a poultry farm**

The poultry farm has a capacity of 700 laying hens and 12,000 slow-growing broilers. The structure is identical to that of a large farm (including 4 hierarchical levels). Regarding the "Logistics" at the lowest level (d1) e-mail is used to forward information from websites, using and sharing Excel files, therefore it is assumed that this level of the department is located in 3rd level of digitization and is estimated as 2. Information is further transferred as the offers are shared via Google Dropbox. Therefore, the higher hierarchical level (c1) of the same department is assumed to be in a level of digitization 5, numerically evaluated with 4. The next two superior levels (a1 and b1) also use Dropbox in their activities, so we assume that they are at the same level of digitalization and are numerically evaluated with the same evaluation as the previous one. Thus, the part of the code corresponding to this department, which has the sequence “a1|b1|c1|d1”, gives the first four digit sequence, part of the whole 20 digit code “4442”.

Regarding the "Consultancy and R&D", the farm has a contract for consultancy services with a research institute, which actually represents the bottom two levels of the hierarchical pyramid. The technical staff (d2) employed in the lowest level of the pyramid work freely with the application "Spreadsheet" of Gmail, therefore the lowest hierarchical level of this department is considered to be in the 5th level of digitalization and is evaluated numerically with 4. The third level handles a cloud-based platform, which uploads data from a digital hand-held balance equipped with an RFID reader to identify chipped birds with an RFID sensor, therefore assumed to be in 6th level of digitization and is rated 5. The top 2 levels (a2 and b2) of the hierarchy of the department work freely with Google Dropbox as well as with Gmail's "Spreadsheet", hence, it is believed that they are in the 5th level of digitization and receive grades 4.

The second four-digit combination, part of the 20-digit code responsible for "Consultancy and R&D", becomes "4454", following the sequence "a2|b2|c2|d2" shown in Figure 1.

When assessing the "Production" department, it is taken into account that the lowest level (d3) in the hierarchical pyramid does not work with a computer, but only analog (paper media) are used when keeping primary documentation. This level is rated as 0. The second level of the hierarchical pyramid (c3) works freely with Gmail's "Spreadsheet" application, therefore it is considered to be in the 5th level of digitization and is rated numerically as 4. The rest 2 levels (a3 and b3) of the hierarchy of the department work through Google's Dropbox application, therefore they are considered to be in the 5th level of digitization and receive a rating of 4.Thus, the third four-digit combination of the general code corresponding to this department becomes “4440”, following the sequence of Figure 1 - “a3|b3|c3|d3”.

In the evaluation of the "Administration", all four levels (a4, b4, c4 and d4) of the hierarchical pyramid work with Google's Dropbox and Gmail's "Spreadsheet" and hence are located in digitization level 5, which is evaluated with a 4. Therefore, the third four-digit combination of the general code is "4444", following the sequence of Fig.1 - "a4|b4|c4|d4".

The last of the five departments, "Sales", uses the structure and staff of the "Production" and is assessed with the same rating, therefore the third four-digit combination of the general code is "4440" and repeats completely the assessment of the "Production" department. The assessment of the level of digitization of the poultry farm is shown in Table 4.

Table 4. Assessment of the degree of digitalization of the structure of a poultry farm

| **Level** | **Department** | | | | | **Mean for the level** |
|---|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales | |
| 1 Level | 4 | 4 | 4 | 4 | 4 | 44.44% |
| 2 Level | 4 | 4 | 4 | 4 | 4 | 50.00% |
| 3 Level | 4 | 5 | 4 | 4 | 4 | 60.00% |
| 4 Level | 2 | 4 | 0 | 2 | 0 | 26.67% |
| Mean for each department | 46.23% | 58.13% | 37.90% | 46.23% | 37.90% | 45.28% |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The total estimate of the level of digitalisation of the poultry farm according our model is displayed in the right bottom cell in Table 4 and is 45.28%. The code that carries the information of the overall assessment of the poultry farm is given by the cells in the respective columns of Table 4 and is expressed as "4442-4454-4440-4442-4440".

Table 5. Assessment of the efficiency of the departments in the structure of the poultry farm

| Differences in levels | **Departments** | | | | |
|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales |
| 1- next level | 0 | 0 | 0 | 0 | 0 |
| 2- next level | 0 | -1 | 0 | 0 | 0 |
| 3- next level | 2 | 1 | 4 | 2 | 4 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The comparisons between the degrees of digitization for adjacent levels in structure of the poultry farm (Table 5) show that the only negative value was obtained for the second level of the "Consultancy/R&D" department. Measures should be taken to increase the degree of digitization at this level in the department for more efficient management of the farm.

***Assessment of the degree of digitalisation of a pig farm***

In the pig farm, 250 pigs (Mangalitsa and East Balkan Pigs) are raised on pasture. For estimation of the pig farm (Table 6), we used the same method and evaluation table.

Here again, the hierarchical structure of 4 of the departments consists of 4 levels, with the exception of the "Consultancy and R&D", which consists of two levels. In this case, the highest and the lowest levels in the hierarchical pyramid are saved and evaluated as before, while the missing two intermediate levels are marked in the evaluation with the letter code "X".

Table 6. Assessment of the degree of digitalization of the structure of a pig farm

| Level | Department | | | | | Mean for the level |
|---|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales | |
| 1 Level | 4 | 4 | 4 | 4 | 4 | 44.44% |
| 2 Level | 4 | X | 4 | 4 | 4 | 50.00% |
| 3 Level | 4 | X | 4 | 4 | 4 | 57.14% |
| 4 Level | 4 | 2 | 0 | 4 | 0 | 33.33% |
| Mean for each department | 54.56% | 38.89% | 37.90% | 54.56% | 37.90% | 46.23% |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The overall assessment of the level of digitization of the pig farm according to the model we have chosen is 46.23% (Table 6). The information to evaluate the degree of digitization of the pig farm can be expressed in the following 20-digit code: “4444-4XX2-4440-4444-4440”.

Table 7. Assessment of the efficiency of the departments in the structure of the pig farm

| Differences in levels | Departments | | | | |
|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales |
| 1- next level | 0 | 2 | 0 | 0 | 0 |
| 2- next level | 0 | X | 0 | 0 | 0 |
| 3- next level | 0 | X | 4 | 0 | 4 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The lack of negative values (Table 7) shows that no problematic departments in the pig farm have been found.

***Assessment of the degree of digitalization in cattle farm***

The farm has two herds of cattle (dairy of approximately 50 dairy cows and beef of 80 castrated bulls for slaughter), which are reared on pasture during the year. As with the pig farm, 4 of the departments are made up of 4 hierarchical levels, with the "Consultancy and R&D" again being limited to only 2 levels (the highest and the lowest). The results for the assessment of the degree of digitization of the beef farm are shown in Table 8.

Table 8. Assessment of the degree of digitalization of the structure of a cattle farm

| Level | Department | | | | | Mean for the level |
|---|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales | |
| 1 Level | 4 | 4 | 4 | 4 | 4 | 44.44% |
| 2 Level | 4 | X | 4 | 4 | 4 | 50.00% |
| 3 Level | 4 | X | 2 | 4 | 2 | 42.86% |
| 4 Level | 2 | 2 | 0 | 2 | 0 | 20.00% |
| **Mean for each department** | **46.23%** | **38.89%** | **30.75%** | **46.23%** | **30.75 %** | **39.33%** |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The overall assessment of the level of digitization of the cattle farm is 39.33% (Table 8). Information to assess the degree of digitalization of the cattle farm can be expressed in the following 20-digit code: “4442-4XX2-4420-4442-4420“.

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Table 9. Assessment of the efficiency of the departments in the structure of the cattle farm

| Differences in levels | Departments | | | | |
|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales |
| 1- next level | 0 | 2 | 0 | 0 | 0 |
| 2- next level | 0 | X | 2 | 0 | 2 |
| 3- next level | 2 | X | 2 | 2 | 2 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

When evaluating the efficiency of the departments, no negative differences were found in the degree of digitalization of the structure of the farm, which, according to our model, shows that the incoming information is effectively used by all the departments.

***Assessment of the digitalization of the sheep farm***

The sheep farm consists of 160 sheep. The farm raises sheep for milk and offspring, mainly for meat. The structure of this farm is composed of 3 hierarchical levels, with level 2 missing, except for "Consulting services and R&D" and "Administration" departments. The "Consulting services and R&D" lacks any hierarchical structure, as the highest level in the pyramid performs similar functions. In the "Administrative" department, the hierarchical pyramid is composed of only 2 levels (the highest and the lowest). The results of the application of the model for the evaluation of the digitization of the sheep farm are shown in Table 10.

Table 10. Assessment of the degree of digitalization of the structure of the sheep farm

| **Level** | **Department** | | | | | **Mean for the level** |
|---|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales | |
| 1 Level | 4 | 4 | 4 | 4 | 4 | 44.44% |
| 2 Level | X | X | X | X | X | 0.00% |
| 3 Level | 4 | X | 2 | X | 2 | 38.10% |
| 4 Level | 2 | X | 0 | 2 | 0 | 16.67% |
| Mean for each department | 44.97% | 44.44% | 24.34% | 38.89% | 24.34% | 24.80% |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

The assessment of the level of digitization of the sheep farm according to the model we have chosen is 24.80% (Table 10). Information from the evaluation of the degree of digitization of the sheep farm is given by the following 20-digit code: "4X42-4XX-4X20-4XX2-4X20".

Table 11. of the efficiency of the departments in the structure of the sheep farm

| Differences in levels | Departments | | | | |
|---|---|---|---|---|---|
| | Logistics | Consultancy /R&D | Production | Administration | Sales |
| 1- next level | 0 | X | 2 | 2 | 2 |
| 2- next level | X | X | X | X | X |
| 3- next level | 2 | X | 2 | X | 2 |

Source: Authors' original model for evaluation of the digitalization in the studied farm.

When evaluating the efficiency of the departments in the hierarchical structure of the sheep farm (Table 11), no negative differences in the degree of digitalization between the different levels were found.

## CONCLUSIONS

A model was tested for the assessment of digitization of a stock farm located in southwestern Bulgaria. The estimates of the degree of digitization of the studied farms were relatively low and varied between 46.23% (the highest) for the pig farm and 24.80% (the lowest) for the sheep farm. We consider that these low ratings were largely due to the high demands of the model we propose. With few exceptions, the evaluations of the efficiency of data transfer between the different levels of the departments in the surveyed farms were high. The evaluated farms are small-scale farms for the country. For a comprehensive assessment of the degree of digitization of the livestock sectors in the country, survey information on as many farms as possible is needed, which can be done in future research.

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# ASSESSMENT OF WOMEN'S ROLE IN FISHING ACTIVITY

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***Abstract***

*This paper examines the specific roles of men and women at various phases of fishing activity. There were a total of 266 fisher respondents randomly selected from six identified fishing sites in Leyte, Philippines. Data were gathered through face-to-face interview using a pre-tested questionnaire. Both descriptive statistics and independent sample t-test were carried out to analyze the primary data gathered. Based on the findings, men primarily take part in decision makings pertaining to fishing activity such as fishing time, place, and quantity of fish catch to sell. They also are the in-charge in the preparation of the fishing paraphernalia and the ones who sell and bring the fish catch to their preferred marketing outlets. Meanwhile, women played vital roles in cooking the food for fishing activity and the ones who compute, record and keep the earnings from fishing activity.*

***Key words*****:** *fishing, fishers, gender roles*

## INTRODUCTION

Fishing has been an important source of livelihood for Filipinos having fish as the country's second staple food next to rice. According to Philippine Statistics Authority [10], the fishing industry provided employment to around three percent of the country's labor force in 1998. There are about 36 million people who are employed directly through fishing [3] and as many as 200 million people derive direct and indirect income from fish [5].

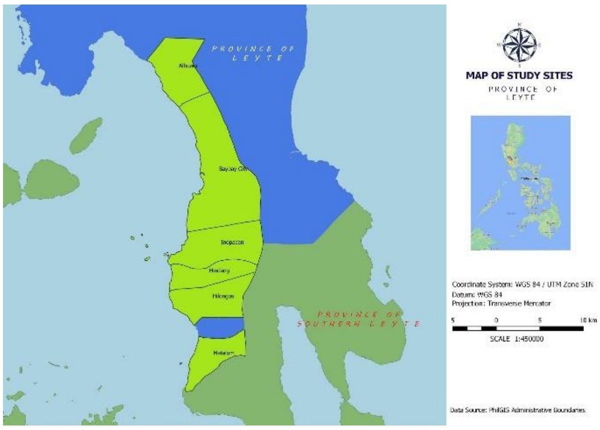
Women make significant contributions to fisheries and agriculture and many studies have been done to detect the trends of working female labor in agriculture. The various challenges of women involved in fishing activities was explored [6]. The roles of women from the fishery sector of Pantar Island was examined [4]. The roles of women in fishing industry was also being studied [2].

Knowledge of gender roles is an important part of fisheries management, it allows interventions to be tailored to specific groups of fishers. This study documents the participation of women in fishing activity and understand the roles of both men and women from Leyte, Philippines at various phases of the fishing activity.

## MATERIALS AND METHODS

### Location of the study

The study took place in Leyte, Philippines Fisher respondents were randomly selected from the six (6) fishing sites in Leyte , namely Matalom, Hilongos, Hindang, Inopacan, Baybay and Albuera (Map 1).




Map 1. Study sites
Source: [9].

### Data collection and sampling technique

The data were gathered through face-to-face interview using a pre-tested questionnaire. A survey was done from 266 fisher respondents taken randomly from selected fishing grounds in Leyte, Philippines. The responses were analysed using descriptive statistics such as means, standard deviation, variances,

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minimum and maximum. Frequency counts and percentages were also computed in the assessment of gender roles in fishing activity. An independent sample t-test was conducted at a 5 percent level of significance to determine the statistical significance of mean differences between the male and female groups with regard to various fishing variables, including fishing days, fishing hours, travel time, fishing costs, and catch. Social Packages for Social Sciences or SPSS (v. 20) was used to facilitate the data analysis.

## RESULTS AND DISCUSSIONS

### Profile of the fisher respondents

Both male and female fisher respondents from selected fishing sites in Leyte, Philippines have an average of three (3) dependents. According to Table 1, female fishers have more years of formal education than males, on the average. Female fishers averagely reached 1st year high school with eight (8) years of formal education while male fishers completed Grade-6 level with seven years of schooling. A typical Filipino family has five (5) people [8], which is the mean household size of the fisher respondents in Leyte, Philippines.

Table 1. Profile of the fisher respondents

| Sex | | Dependents | Education | Household size |
|---|---|---|---|---|
| Female | Mean | 3 | 8 | 5 |
| | Std. Dev | 1.67 | 2.57 | 1.92 |
| | Minimum | 0 | 5 | 1 |
| | Maximum | 5 | 12 | 7 |
| | Variance | 2.78 | 6.61 | 3.69 |
| Male | Mean | 3 | 7 | 5 |
| | Std. Dev | 2.18 | 3.09 | 2.16 |
| | Minimum | 0 | 0 | 1 |
| | Maximum | 13 | 20 | 13 |
| | Variance | 4.75 | 9.57 | 4.67 |

Source: Author's calculation and analysis (2022).

### Characteristics of the respondents' fishing activity

Fishing is the main source of income for the majority of the female fishers in Leyte, Philippines (88.9%), as well as for male fishers (94.2%) (Figure 1). The majority of females (77.8%) joined fishing organizations, compared to more than half (64.5%) of the males who did not. Membership to organization is important among fishers because it enables them to participate in economic decision-making [12]. Moreover, in terms of boat ownership, majority of women fishers primarily owned the fishing boats they are using (66.7%). Only a small percentage of men used motorized boats (36.3%), compared to women (66.7%) who use non-powered boats. The usage of motorized boats is crucial for fishers due to the following benefits such as increased fishing trips, higher mean weight, and higher CPUE [7]. Furthermore, by using motorized boats, the average CPUE increased because fishers can access more fishing grounds that are relatively farther from nearshore fishing areas that are regularly accessed [13].

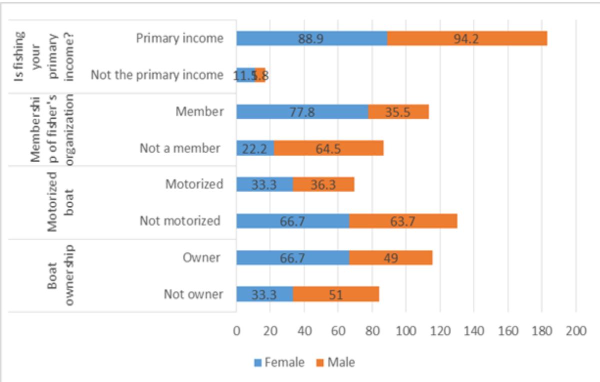


Fig. 1. Characteristics of fishing activity, by gender
Source: Author's calculation and analysis (2022).

Male and female fishers dedicated six (6) days in a week for their fishing activity and both individuals spent roughly six (6) hours in a day fishing. Male fishers travelled farther (1.42 vs. 1.04 hours) than female fishers which suggests that, when other variables are held constant, males capture fish farther than females however no sufficient data to support this claim at 5% level of significance (Table 2).

Male fishers spent more money on their fishing activities than female fishers, at 283.28 PHP (5.03 USD) and 177.67 PHP (3.15 USD), respectively, however there is no enough data to support this claim. Lastly, men catch more fish than women, 2.88 kg compared to 2.31 kg, the mean difference is not statistically significant at 5% level.

Table 2. Descriptive analysis of fishing variables

| Descriptive analysis indicators | Fishing days in a week | Fishing hours in a day | Travel time (hours) | Daily cost in fishing (PHP) | Catch (kg) |
|---|---|---|---|---|---|
| **Female** | | | | | |
| Mean | 6 | 6.43 | 1.04 | 177.67 | 2.31 |
| Std. Deviation | 1.394 | 3.669 | .724 | 218.668 | 1.108 |
| Minimum | 3 | 1 | 0 | 5 | 1 |
| Maximum | 7 | 13 | 2 | 704 | 4 |
| Variance | 1.944 | 13.461 | .524 | 47,815.750 | 1.227 |
| **Male** | | | | | |
| **Mean** | 6 | 6.43 | 1.42 | 283.38 | 2.88 |
| **Std. Deviation** | 1.766 | 3.499 | 1.038 | 306.906 | 1.596 |
| **Minimum** | 1 | 1 | 0 | 5 | 0 |
| **Maximum** | 7 | 16 | 6 | 1,690 | 12 |
| **Variance** | 3.119 | 12.240 | 1.078 | 94,191.252 | 2.548 |

Source: Author's calculation and analysis (2022).
Note: 1 USD = 56.34 PHP (22 July2022).

**Assessing the roles of men and women at various phases of fishing activity**

Fishing activity requires various decision-makings, such as choosing a specific time of the day or specific days of the week when to catch fish. Based on the findings, almost every male fisher respondent claims to be involved in this matter (93.6 %). Meanwhile, there are necessary preparations needed before fishers go for fishing such as preparing their paraphernalia and cooking some food needed to bring to the fishing areas since it may took long hours before they get home. As seen in Table 4, mostly men prepares the fishing paraphernalia since they are the ones who usually go to the fishing area and they are more knowledgeable on this matter, almost three-fourths of the overall (74%). Women are mainly responsible in cooking the food, which comprises 70% of the total fisher respondents since they considered household managers. Women are more knowledgeable about the needs of a household, whether it is food or daily necessities [1].

Males typically make the decisions on whether to keep their catch for household consumption or sell it (73%), as well as how many fish will be sold in the market (77.8%). Males are also the in charge of where to sell their catch (82%) and are also the ones who would transport it to their chosen markets (76%).

Table 3. Independent T-test results

| | t | df | p-value | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper |
| Fishing days in a week | 1.459 | 264 | .179 | .697 ns | .478 | -.385 | 1.779 |
| Fishing hours in a day | -.006 | 264 | .995 | -.007 ns | 1.188 | -2.347 | 2.332 |
| Travel time (hours) | -1.100 | 264 | .272 | -.384 ns | .349 | -1.072 | .304 |
| Daily cost in fishing (PHP) | -1.023 | 264 | .307 | -105.715 ns | 103.299 | -309.108 | 97.679 |
| Catch (kg) | -1.057 | 264 | .291 | -.568 ns | .537 | -1.625 | .490 |

Source: Author's calculation and analysis (2022).
*ns – Not significant*

Keeping clear records of income and expenses brings peace of mind, helps monitor progress toward goals and saves time and money [11]. Fishing activity has corresponding costs that needs to be documented by fishers. Females usually records their fishing expenses (63.9%) while a few were done by males (33.5%).

After the fishers sell their catch to their preferred marketing outlets, females usually compute the income earned and evaluate whether fishing activity is profitable or not (74.4%).

Table 4. Gender roles in decision-making and preparation

| Fishing activity | Gender | Frequency | Percentage |
|---|---|---|---|
| Decides when to fish | Female | 13 | 4.9 |
| | Male | 249 | 93.6 |
| | Both | 4 | 1.5 |
| | *Total* | *266* | *100* |
| Prepares fishing paraphernalia | Female | 57 | 21.4 |
| | Male | 197 | 74.1 |
| | Both | 12 | 4.5 |
| | *Total* | *266* | *100* |
| Cooks food before fishing | Female | 187 | 70.3 |
| | Male | 63 | 23.7 |
| | Both | 16 | 6 |
| | *Total* | *266* | *100* |

Source: Author's calculation and analysis.

As household managers, females keep the earnings of fishing activity (75.9%) since they are the ones who handle the budget and the in charge in purchasing the household needs (e.g. foods, clothing).

Table 5. Gender roles in recordkeeping and other related activities

| Fishing activity | Gender | Frequency | Percentage |
|---|---|---|---|
| Who decides whether to sell your catch or not | Female | 37 | 13.9 |
| | Male | 194 | 72.9 |
| | Both | 35 | 13.2 |
| | *Total* | *266* | *100* |
| Who decides for the marketing outlet | Female | 36 | 13.5 |
| | Male | 218 | 82 |
| | Both | 12 | 4.5 |
| | *Total* | *266* | *100* |
| Who decides the quantity to be sold | Female | 45 | 16.9 |
| | Male | 207 | 77.8 |
| | Both | 14 | 5.3 |
| | *Total* | *266* | *100* |
| Who brings the fish catch to marketing outlet | Female | 61 | 22.9 |
| | Male | 192 | 72.2 |
| | Both | 13 | 4.9 |
| | *Total* | *266* | *100* |

Source: Author's calculation and analysis (2022).

## CONCLUSIONS

There has been no statistical significant differences on the means of male and female groups based on fishing days, fishing hours, travel time, daily cost in fishing, and catch. Fisher respondents were asked on both men and women's specific roles in their fishing activity. The basis for the analysis were on majority of their responses using frequency counts and percentages. Given the results, the primary roles of men were on decision makings in terms of when to fish, whether to sell the fish catch or not, the place to market the fish, the kind, price, and quantity of fish catch to be sold. Other roles of men involved the preparation of the fishing paraphernalia, selling and bringing the catch to their preferred marketing outlets. Meanwhile, women play important roles in cooking food before fishing as well as keeping, computing and recording the earnings from the fishing activity. In general, women have less access to decision-making than males, yet they do participate in financial affairs.

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# ROMANIA'S MOUNTAIN AREAS - PRESENT AND FUTURE IN THEIR WAY TO A SUSTAINABLE DEVELOPMENT

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***Abstract***

*The paper purpose was to analyze the present situation of the mountain areas in Romania from a socio-demographic, economic and environmental point of view in order to identify the main positive and negative aspects and to establish what objectives and measures have to be considered for assuring the sustainable development of the mountain regions in the coming future. The statistical data provided by Eurostat, FAO, National Institute of Statistics and National Agency for Mountain Areas were statistically processed in their dynamics using trend regression equations, graphical illustration and comparisons. The results pointed out that the Carpathians cover 37.8% of Romania's area and are predominantly rural. The share of the mountain municipalities is just 37.8%(12th position in Europe), the residents account for 5.53 million (6th position) meaning 25% in the total population (11th position), agriculture (mainly animal growing) and forestry are the main activities. In 2021, in the mountain regions there were registered 3,147 producers who carried out 1,164 mountain products, the highest weight belonging to vegetal, dairy and beekeeping products whose sale was assured by 135 Local Gastronomic Points. The contribution of the mountain areas to GDP was Euro 48.7 million, for which Romania came on the 8th position among other European countries. The actual challenges the mountain areas are facing are: the decline and aging of the population, migration of young people to the cities, weak infrastructure, livestock decrease, grasslands degradation, weak promotion of mountain products, lack of connectivity and communication between settlements, a low valorization of the natural and human resources. In consequence, as the Mountain Law provides, it is needed a new approach regarding the development of the mountain economy by valorizing in a more effective way all the resources, paying attention to the diversification of the activities, creating new jobs, stimulating entrepreneurship to increase production (agriculture, forestry, handicrafts etc) and encourage more services (education, medical, cultural, tourism, trade, credit etc), facilities for supporting young people to remain in the localities of origin, improving infrastructure (roads, bridges, houses and village restoration, connectivity to IT and mobile network, digitalization etc), involving both the local authorities and all the residents to intensify their efforts to support the mountain areas in their way to a sustainable development upwards 2030.*

**Key words:** *mountain areas, strengths, weaknesses, challenges, sustainable development*

## INTRODUCTION

Mountain areas are of a special beauty and greatness, grace to their peaks, valleys and depressions, fairy tale landscapes, virgin forests of a large tree and shrub diversity, wild flora and animals, water sources, lakes and glaciers, fantastic rainfalls, fascinating caves, human settlements where people is dealing with agriculture and food manufacturing, forestry, fishing, handicrafts, tourism and agro-tourism, and the sold products and services ensure a decent income and the living standard to the local population.

Therefore, the mountain areas have a vital importance from an economic, social, cultural and environmental point of view [17].

The word "mountain" symbolizes " adventure, escape, challenge and conquest" [43].

In order to encourage sustainable development, United Nations General Assembly have established that mountains deserve to be celebrated due to their role on the Planet. It was designated December 11 as the International Mountain Day. Every year the celebration of the International mountain Day has a specific topic, and in 2022, the theme is "Women move mountains" [19].

The importance of the mountains areas in the world is reflected in Fig.1.

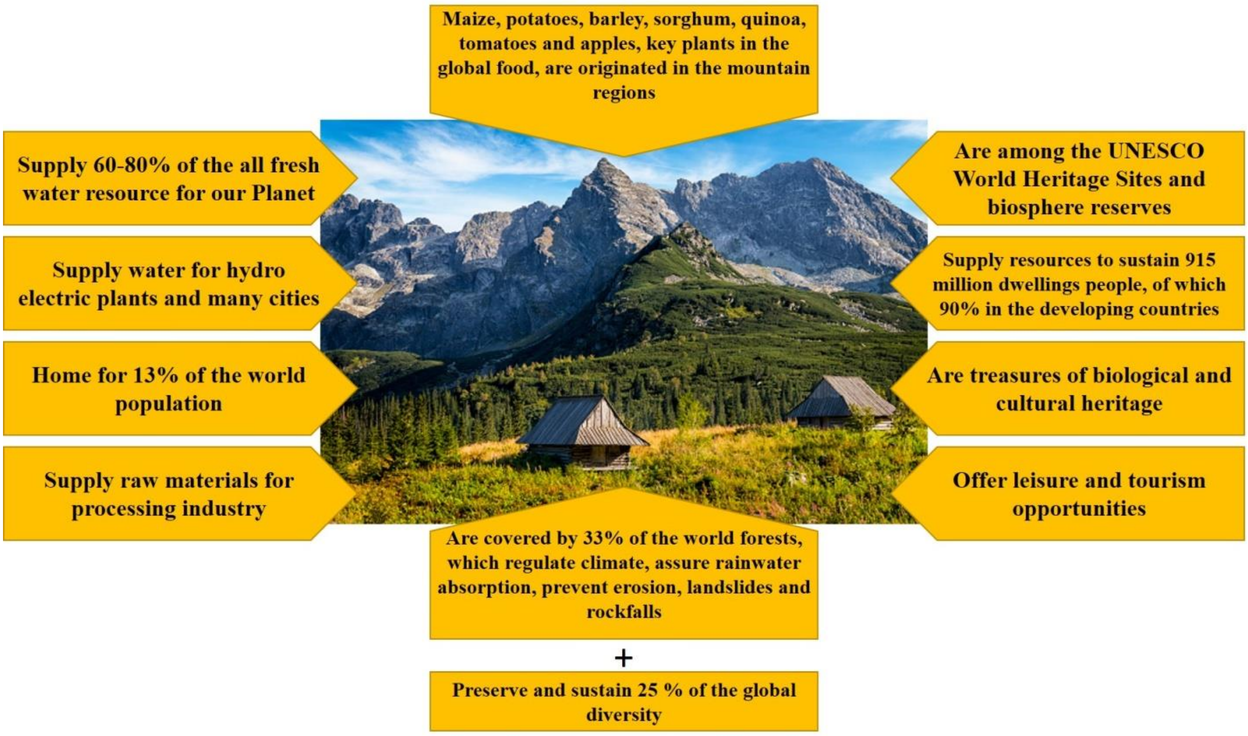


Fig.1. The importance of the mountain areas in the world
Source: Own design based on [12].


a. b.

Map 1. Europe's mountain ranges
Sources: (a) [49] and (b) [16].

Europe has many mountain ranges differently positioned on the map of the continent. They have various dimensions, climate conditions, natural and human resources, and economic development (Map 1).

There are 10 great mountain ranges and up towards 100 small mountains which represent the heritage of the old continent. The largest mountain ranges are the Alps, the Pyrenees, the Carpathians, the Caucasus Mountains, the

Dinaric Alps, the Scandinavians, the Scottish Highlands, the Apennines, the Dolomites and the Balkans [46] (Map 1).

The European countries with the largest surface covered by mountain areas, in the decreasing order are: Spain, Norway, Italy, France, Greece, Iceland, Romania, Austria, United Kingdom, Bulgaria, Germany and Switzerland. The largest mountains belong to Spain (279,865 km$^2$) and the smallest ones to Liechtenstein (160 km$^2$) (Fig. 2).

The surface of the mountains has a deep impact on air, soil, water quality and also on health and food security and safety.

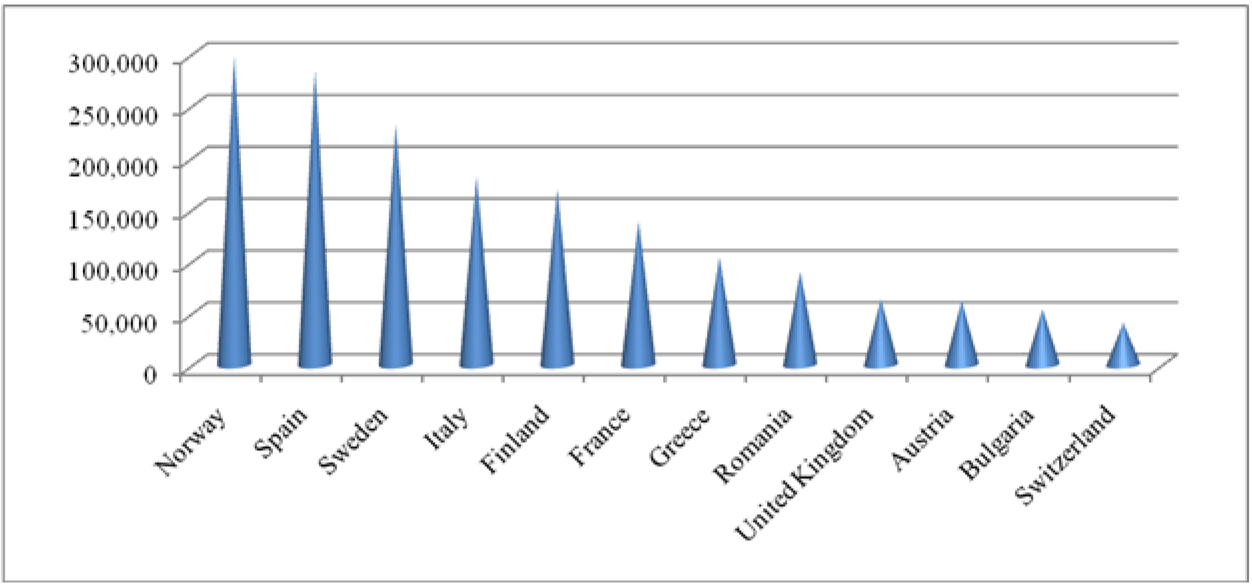


Fig. 2. The main European countries with large mountain areas (km$^2$)
Source: Own design based on the data from [15].

The most numerous mountain population is in Italy, Spain, France, Germany, Switzerland, Romania, Greece, Austria, Bulgaria, Slovakia, Norway, United Kingdom, Czechia, Poland, and Slovenia. Italy is on the top position for the largest number of residents, more than 18.3 million, in the settlements of the mountain areas.

The European countries with the highest share of population living in the mountain areas are: Switzerland, Slovenia, Norway, Austria, Greece, Slovakia, Bulgaria, Spain, Italy, Portugal, Romania. In Switzerland, 84% of the residents are in the mountain regions, while in Romania about 25%. Lower percentages are also in other countries.

A study made in 29 countries including the EU, Norway and Switzerland pointed out that the mountain municipalities cover 1.9 million km$^2$, representing 40.6% of the total area. About 94.3 million inhabitants, accounting for 19.1% of the total population live in the mountain regions, either directly (20%) or at a specific distance ranging between 10 and 50 km from the mountains [39].

The highest share of the mountain municipalities is in the following countries: Switzerland 93.3%, Norway 92%, Slovakia 77%, Greece 77.88%, Austria 73.4%, Italy 60%, Spain 56%, Sweden 51%, Finland 49.4%, Bulgaria 49%, Cyprus 47%, Romania 37.8%, Czechia 32% [15].

The economic activities carried out in the mountain regions have an important contribution to GDP. The highest contribution to GDP in Euro Million, coming from the mountain areas, is given by Italy (753.5), Spain (702.1), France (404.3), Germany (229.3), Austria (183.6), Greece (109.1), United Kingdom (58.8), Romania (48.7), Slovakia (40.4), Portugal (40.2), Slovenia (33.7), Bulgaria (33.5), Czechia (25.5), Poland (20.2), Croatia (10.5) and Belgium (5.2).

Employment rate continues to grow due to the multiple mountain activities and higher attractiveness of entrepreneurship. However, employment rate is raising by different rates from a country to another as follows: Slovakia 12.3%, Spain 11.7%, Bulgaria 11.7%, Greece

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11.5%, Slovenia 11.3%, Portugal 10.8%, Czechia 10.4%, Romania 7.2%, Croatia 6.4%, Italy 5.3%, United Kingdom 3.8%, Austria 2.9%, Germany 1.3%.

The mountain areas represent 30% of the EU territory, are home for 57% of the population and contribute by 46% to GVA.

Mountain areas have a high sensitivity to the climate change which causes glaciers melting, huge rainfalls followed by floods, landslides, soil erosion, damages to infrastructure and settlements, financial losses, and also loss of animals and even human lives.

But, the cultural heritage built across the time by the history of the continent is very rich [7].

The big challenges for the mountain areas at present are the depopulation and the lack of enough services.

However, in France, Italy, Germany, Switzerland and Austria, the mountain areas have known the highest economic-development during the last 40 years [34].

In this context, the aim of the paper was to analyze the mountain areas of Romania in order to point out their actual strengths and weaknesses, challenges and needs regarding their future to a sustainable development.

## MATERIALS AND METHODS

First of all, the research work needed a documentation regarding the importance of the mountain areas at the world and European level, and in Romania, based on the study of various written materials like Reports of international and national forums, published books and scientific articles.

Secondly, the statistical data have been collected from Eurostat, FAO, and National institute of Statistics, and also from National Agency for the Mountain Areas.

The main aspects approached in this study have been the following ones:

- The importance of the mountain areas for our Planet;
-The main mountain ranges exiting in Europe and the position of the Carpathians among them;
-The Carpathians - surface, altitudes, groups of mountains;
-Human settlements and their features;
-Demographic aspects: number of residents and their share in Romania's population, age, education level, migration;
-Infrastructure;
-Mountain economy: (i) agriculture: land use, vegetal and animal growing; (ii) food processing and marketing; ( iii) mountain producers, products and local gastronomic points; (iv)forestry, (v)handicrafts, (vi) tourism etc.
-Contribution of the mountain economy to GDP;
-Living standard of the population;
-Environmental aspects;
-Legal framework and administrative bodies.

For each aspect have been identified the main aspects of interest pointing out both the positive and negative aspects and the challenges the mountain areas are facing.

Finally, there were presented the needs and the main direction of development of the mountain regions of Romania to success in their way to a sustainable development from an economic, social, cultural and environmental point of view.

The statistical data were processed in their dynamics and the results were presented graphically, in some cases the trend regression equations were used to reflect much better the main tendency.

When analyzing various indicators, comparison method was utilized to evaluate Romania's position among other European countries.

## RESULTS AND DISCUSSIONS

"Mountain is not just a part of the Universe, but a un Universe itself" as affirmed by Eugen Barbu, one of the greatest Romanian writers and journalists, correspondent member of the Romanian Academy [31].

Besides the International Mountain Day which is celebrated on December 11 every year since 2003, in Romania, the National Mountain Day is September 14.

**The Carpathians of Romania**

Romania has 238,391 km$^2$ surface, of which 90.39 thousand km$^2$ belong to the mountain area, meaning 37.9% of the territory of the country. Romania has the largest mountain range located inside of a country in Europe, and for this reason, Romania is considered a Carpathian country [20].

The Carpathians represent the North-Eastern alpin montaneous system which starts from Vienna basin and keeps upward to the Timoc Valley along of 1,500 km and covering 170,000 km$^2$ surface of Europe. On the Romania's territory, their length is 910 km.

Of the 90.38 thousand km$^2$ of the Romania's mountains, 35,660.6 km$^2$ belong to the Eastern Carpathians (39.3%), 14,653.3 km$^2$ (16.1%) the Apuseni Mountains, 39,952 km$^2$ (44.2%)the Southern Carpathians, and 131 km$^2$ (0.4%) the Macinului Mountains [15] (Map 2).

Map 2. Map of Romania's relief - The Carpathians (Brown color)
Source: [47].

About 90% of their surface is situated at an altitude below 1,500 m, but 85% of their area is over 2,000 m and is situated between the Prahova Valley and the Timis-Cerna aisle.

Romania's relief is like an amphitheater, proportionally disposed including 28% mountains over 800 m, 42% hills and plateaus (200-800 m) and 30 % plains below 200 m.

The Carpathians ring surrounds Transilvania depression and the highest peak is Moldoveanu at 2,544 m altitude in the Fagaras Mountains.

**Human settlements**

In the mountain areas of Romania, there are 80 cities, 3,560 villages and more than 850,000 traditional households, owning about 3 million ha agricultural land and 4 million ha forests.

In the Carpathians, large areas are predominantly rural areas and just a few localities are classified in the urban category like towns and cities [9].

Romania has just 37.8% share of the mountain municipalities in the total of the country, coming on the 12th position in Europe after Switzerland, Norway, Slovakia, Greece, Austria, Italy, Spain, Sweden, Finland, Bulgaria and Cyprus [15].

The spectacular alpine areas alternate with valleys and intra-Carpathian depressions, where the human settlements could be found even up to 2,000 m altitude [1].

Among of settlements situated at a high altitude, there are mentioned here just a few:

-Maguri Village, Maguri-Racatau Commune, at 45 km from the city of Cluj-Napoca. The small locality ranges between 1,250 to 1,400 m altitude, has a surface of 13,000 ha, 390 houses, and 918 inhabitants. It is an isolated village, the access being very difficult even in summer season [6, 42].

-Predeal, Brasov County, is the city situated at the highest altitude (1,030-1,110 m) and has 58.4 km$^2$ surface and 4,755 inhabitants. It is well-known as one of the most beautiful mountain resorts in the Prahova Valley, as it offers tourist routes in summer season and one of the best ski slope in Romania [8].

-Fundata Village, Brasov County, is situated at 1,360 m altitude, being considered a "touristic village' since many decades ago [2].

-Sirnea Village, Brasov County, situated at 1,400 m altitude is also a "touristic village" where tourists may benefit of fresh air, spending their holidays for leisure and short trips, enjoying local traditional food and crafts [48].

-Plesa Village, Suceava County, is situated in North Bucovina, in the proximity of Gura Humorului, and is a specific Polish village [5].

Large surfaces of the Carpathians are predominantly rural, and just a few are classified as towns or cities. Despite than rural areas have important land resources, forests, human capital and tourism opportunities, the gaps between the rural areas and the urban ones has been accentuated due to the economic decline in the rural space.

**Demographic aspects**

In the mountain areas of Romania there are about 5.53 million inhabitants who are accustomed to live in the mountain conditions in the small localities either communes, villages or cities. Their share in the total population is 25%. Romania comes on the 6th position in Europe for the population living in the mountain regions, after Italy, Spain, France, Germany and Switzerland (Fig. 3).

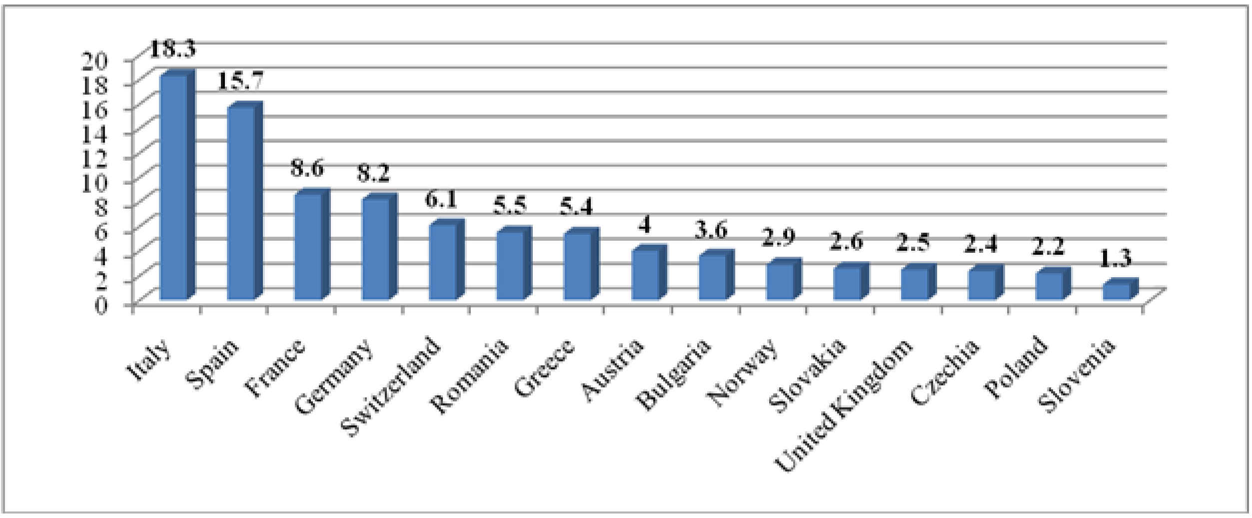


Fig. 3. The European countries with the most numerous population living in the mountain areas (Million)
Source: Own design based on the data from [15].

Taking into consideration the weight of the inhabitants living in the mountain areas in the total population of the country, Romania comes on the 11th position with 25%, after Switzerland, Slovenia, Norway, Austria, Greece, Slovakia, Bulgaria, Spain, Italy and Portugal (Fig. 4).

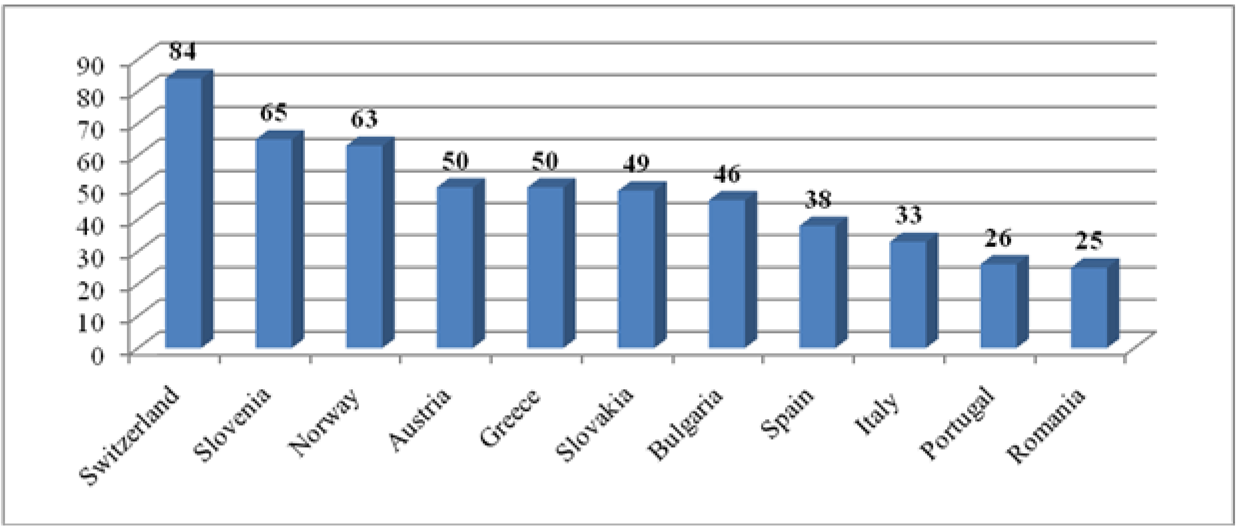


Fig. 4. The European countries with the highest share of population in the mountain areas ( %)
Source: Own design based on the data from [15].

The general features of the population are: aging, the decline of the number of residents, mainly of the young people, low training level reflected by the limited number of schools and their educational level (primary schools, rarely gymnasium level), lack of vocational training, lack of mobility from a locality to another, lack of support for developing entrepreneurship, lack of facilities to communicate and of physical connections from a settlement to another.

The main reasons why the young people leave their place of origin are: the desire to have a comfortable life style in the urban areas, to look for jobs in the cities or abroad in order to be better paid, to benefit of more opportunities to study (high schools, faculties etc), to have access to a large variety of commercial services, to be permanently connected to internet and mobile network, to have more options from where to choose a better accommodation, to have access to a large range of cultural and sport events [14].

**Infrastructure**

In Romania, the mountain infrastructure is of poor quality and the access is difficult, as less than 8% of communal roads and railway network are weak. However, the main transit roads like in the Prahova Valley and the Olt Valley, the Transfagarasan and Transalpina, are better maintained, but the traffic is very intensive, exceeding the road capacity.

In many settlements situated at higher altitudes, there are no electricity, water supply, sewerage, waste collection and processing, transportation means and the digital connectivity is not sufficient or missing.

All these aspects reflect a low living standard of the population and that life and work are difficult in the mountains.

**Economic aspects**

***Agriculture*** is the key sector developed in the mountain areas, as it provides food for the local households and communities and also sustaining the mountain economy. But, agriculture development is different from a region to another and from a country to another, being high gaps between the European states.

*Land* is used for cultivation of various agricultural crops (mainly vegetables etc), in most of cases practicing traditional systems, but we could find also abandoned surfaces which determine soil degradation. In small farms, there are raised dairy cows, sheep and goats, a few pigs, and horses for drafting the carriages.

The mountain land fund of Romania includes: pastures and meadows with the highest share: 45.1% and, respectively 33.2%, summing 78.3%, arable land 20% and the remaining represents orchards and nurseries 1.5% and vineyards and nurseries 0.1% (Fig. 5).

*Vegetal farming*. The farmers are adapted to the specificity of their work in the mountain conditions, large surfaces being on a slope, and the applied technologies are mainly extensive. The wealthier farmers look to be more interested in small mechanization for working the mountain slopes [13].

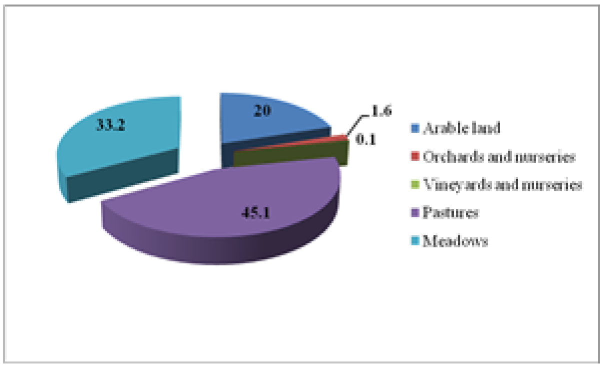


Fig. 5. The structure of land fund in the mountain areas (%)
Source: Own design based on the data from [45].

*Animal farming* involves grazing with dairy cows, sheep and goats, but in an extensive way, rarely in an organized grazing system based on animal rotation on parcels of optimal dimension correlated with food requirements and the regeneration capacity of the grass. The grassland yield depends on the mountain area, climate, soil quality, floristic composition, and maintenance works. Scientific research has put at the farmers' disposal specific solutions for increasing grassland productivity in different mountain areas [23, 24, 25, 26, 27, 28, 33].

Romania's mountain areas have a rich fund of pastures and meadows. Pastures cover 3.27 million ha (13.7%), and hayfields cover 1.55 million ha (6.5%) [30].

In the mountain livestock has registered a continuous declining trend due to the discriminatory subsidy offered in the year 2007 only to the farmers raising more than 50 sheep, and which in the year 2013 has been allotted only to the farmers growing over 150 sheep.

The decrease in the livestock has led to the reduction of organic fertilizer (manure), to a disturbance in the floristic composition of the grasslands and in consequence to the decline of their grass productivity and implicitly of animal production [40].

The pastoralism has changed in the last decades and transhumance represents just 10% of the sheep flock and is made especially to the plain areas [4].

In other countries, the agriculturists receive a specific support like: investment aids for farming, direct payments, support for maintaining the grasslands, facilities for improving technical endowment, support for organic farming etc.

Compared to other countries, the small support offered to farmers in the mountain areas in Romania reflects that these regions are strongly marginalized compared to the plain and hilly areas.

**Food processing** is mainly oriented to the obtaining of specific traditional products, using preserved technologies and good practices to achieve local products. The main mountain products are: dairy products (milk, cheese made of cow, sheep or goat milk or a mixed milk), eggs, meat products (especially salted meat sorts), various types vegetable products (vegetables as such, canned vegetable mix), jams made of fruit forests and other fruits, natural juices, wines, plum brandy (tzuica), bee products ( honey, polen, royal jelly etc.), bread, bakery and pastries products. Their sorts are determined by the geographical position, soil fertility, climate conditions, local traditions. The mountain products are natural and healthy food, delicious, with a specific flavor, and many of them are already certified.

Food processing is stimulated by the development of tourism and agro-tourism in the mountain areas.

**Mountain product and its market** is for the moment at the beginning. The local producers have an inadequate access to market where to sell their products. Advertising is weak and not efficient, the marketing tools are pale. Products are sold locally, mainly to tourists who visit the locality.

Mountain product is of a different quality compared to other products. It is a natural product as it is obtained either in an extensive system of agriculture with low chemical inputs, or in organic farming or is a traditional product.

Therefore, it is a healthy product as it is made of local row materials, processed using specific local recipes and in private units existing in the mountain settlements.

It has a good correlation between its high nutritive and hygienic quality and sale price.

Mountain products are among consumers' preferences and that is way tourism and agro-tourism in the mountain regions has been intensify during the last decade [37].

In the period 2017-2021, in the mountain areas there were registered 1,164 producers, of which most of them meaning 509 (43.7%) were dealing with vegetable products, 446 (38.3%) were profiled on milk and dairy products, 162 (13.9%) on beekeeping products, 25( 2.1%) on meat and meat preparations, 9 (0.7%) on fish and fish preparations, 9 (0.7%) on eggs and 4 (0.3%) on bakery, pastries etc (Fig. 6).

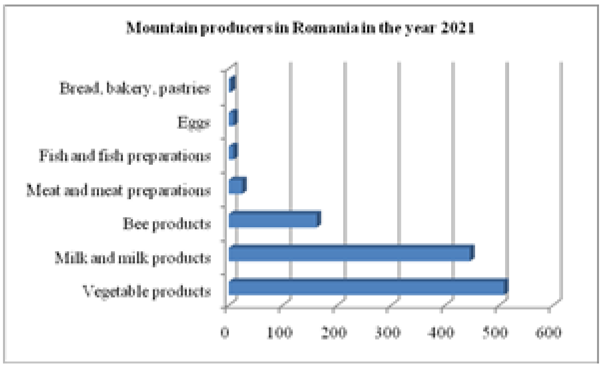


Fig. 6. Mountain producers in the year 2021
Source: Own design based on the data from [30].

Also, in the same period 2017-2021, in the mountain areas were carried out 3,147 "mountain products", of which: 1,695 made of vegetables (53.8%), 936 milk and dairy products (29.7%), 398 bee products (12.6%), 80 products made of meat (2.5%), 25 products made of fish (9.8%), 9 eggs (0.3% ), 4 products from the category bakery etc (0.1%) (Fig. 7).

However, during the period 2018-2021, more and more "Local Gastronomic Points" (LGP) have been created as "authorized units represented by private kitchens situated inside the rural dwellings where food is prepared using culinary recipes specific to the area and destined to be served to maximum 12 consumers.

They have to use raw materials achieved in the own farm and from the local producers or authorized and registered sanitary-veterinary and for food safety" [3].

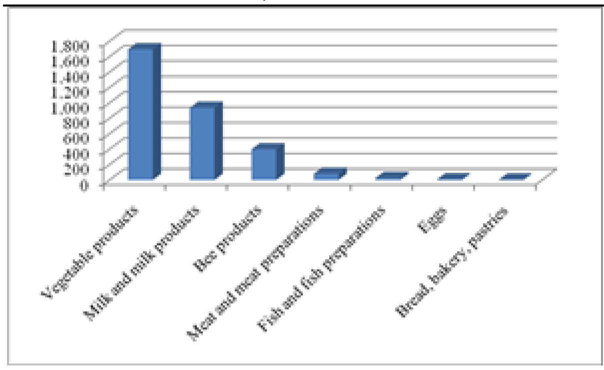


Fig. 7. Mountain products registered in the period 2017-2021
Source: Own design based on the data from [30].

At the national level, in the year 2021, their number accounted for 186 LGP, of which 135 LGP belonged to the mountain areas.

Their purpose is to sustain mountain producers to sell their products and to get the return for their work and to maintain the gastronomic traditions locally [30] (Fig. 8).

**Forestry** is another important economic sector in the mountain areas as it is the habitat for the wild animals, offers protection against natural hazards, assures fresh air, stimulate tourism and relaxation, offers benefits for health, maintains the landscapes value, produce a large variety of forest fruits and hunting opportunities. However, in Romania, forestry is facing huge problems related to the deforestation, with the relatively weak and low efficient means of mechanization, many natural disasters (mainly fires, but also pollution and predators' attack).

Romania's forests are the largest and the best preserved forests in Europe.

Forests represent 6.73 million ha, representing 28.2% of Romania's territory [32].

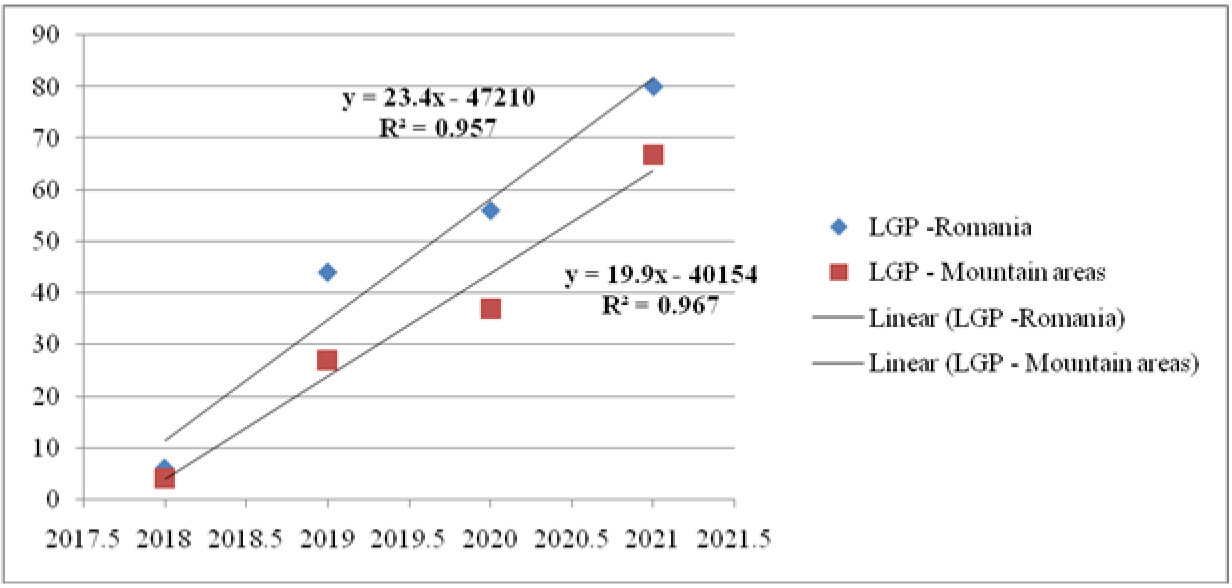


Fig. 8. Dynamics of Local Gastronomic Points (LGP) in Romania and in the mountain areas in the period 2018-2021
Source: Own design and results based on the data from [30].

The vegetation structure includes about 200 species of trees and over 1,200 herbaceous plant species and in addition fungi, mosses, lichens, algae. This species are found in different zones depending on the mountain altitude. Each species plays its specific role and its value in the whole forest ecosystem. If a species disappears from the system, the whole forest balance is affected and compromise the all the other species.

Forests are names "the lungs of the Planet", and this is the reason why we have to protect forests and maintain the pure air which entertain life!

A few residents of the mountain areas are dealing with wood industry which means: tree cuttings, transportation, processing, selling the final products: wood, forest fruits, ornamental trees, Christmas trees, hunting products, fishes etc.

This job brings income to sustain a part of the population living in the mountain areas [21].

**Tourism** in its various forms: rural tourism, eco-tourism, agro-tourism, cultural tourism, sport tourism (skiing, kayaking, rafting etc), religious tourism, health tourism, adventure tourism, recreational tourism, walking, hiking, biking, fishing, hunting, bird watching etc is a "mouth" of fresh air for the mountain economy helping the residents to get additional incomes from offering services of accommodation and board to visitors [35, 36, 41].

The rural mountain tourism is more and more preferred by Romanian tourists as a way to run away from the stressing urban life and artificial food, and to spend their week-ends and vacations in a pictures landscape and enjoying fresh air and delicious traditional and natural local gastronomy [22].

**Handicrafts and other traditional activities** are encouraged to valorize the human resources and local traditions.

**Services** in the mountain areas are not so well developed. It is about education, medical centers, sanitary-veterinary centers, extension, transportation and commercial services, IT communication, energy, tourism etc.

**Small processing industry** is represented by textile production, wood processing, pharmaceutics and leaver goods.

**Living conditions in the mountain areas**

In many cases, the living standard in the mountain areas is lower than in the cities and towns, because of many reasons: the poor infrastructure in villages and communes, lack or low income per family, the low facilities existing in the mountain dwellings. Many house are not well maintained and are degraded or abandoned especially in the isolated regions. The localities are lacked of basic services (school, medical point, bank service, transport, cultural forum etc)

**Environment**

In general, the mountain environment is pleasant and clean, but the human activities like: farming, forestry etc could affect the natural landscapes and could pollute land or diminish agricultural surface, and even leaving the land abandoned.

Erosion, landslides, rockfalls, floods etc produce huge damages to the local communities, destroy dwellings, gardens, kill humans and animals, affect infrastructure, diminish the balance of the eco-systems and the beauty of the landscapes.

Romanian mountains are a treasure of wilderness, including national parks and natural parks, and also protected areas like natural scientific reservations, nature monuments, forestry reserves.

**Contribution to GDP**

Romania comes on the 8th position with Euro 48.7 Million contribution coming from the mountain areas to GDP, after Italy, Spain, France, Germany, Austria, Greece and United Kingdom [15] (Fig. 9).

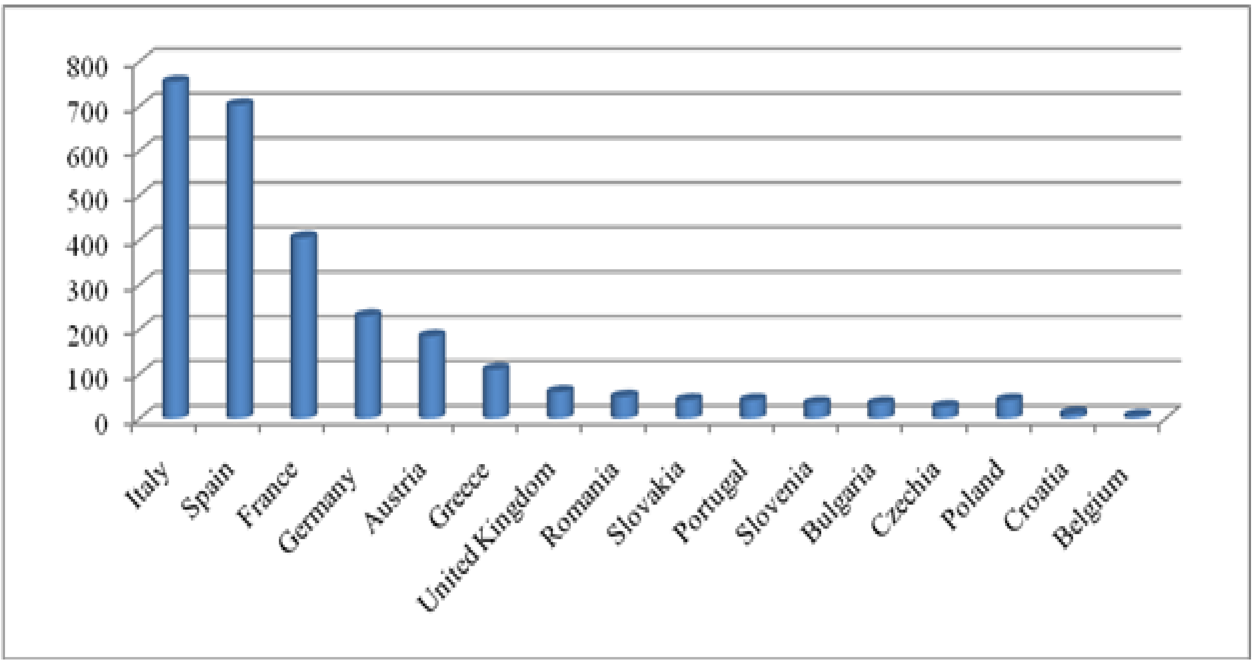


Fig. 9. The European countries with the highest contribution to GSP coming from the mountain areas ( Euro Billion)
Source: Own design based on the data from [15].

**Legal framework and administrative bodies**

The basis of the Mountain Law in Romania was set up in the year 1994, taking into account the criteria to which Switzerland, Italy, France and Austria adhered.At the beginning, the law project had limitations regarding the mountain areas and the delimitations of these regions were officially revised by EC Regulation 1257/1999 and approved by Order of the Minister of Agriculture, Forests and Rural Development No.328/18 May 2004, according to the Decision No.949/2002 drawn by Romanian Government [11].

Other important EU regulations are 1151/2012 regarding the quality schemes for agricultural products and foodstuffs [18] and EC Regulation No.665/2014 concerning the conditions of use of the optional quality term "mountain product"[10].

The Romanian Parliament has approved the Law 197/20 July 2018, which is the Mountain Law, and was published in the Official Gazette No.659/30 July 2018 [38]. This law regulates the ways to protect and assure the sustainable and inclusive development of the mountain area by: valuing the natural and human resources, increasing the living standard, stabilizing the population, maintaining the cultural identity, increasing the economic power locally and nationally under the condition of the maintenance of the ecologic balance and the protection of the natural environment EC Regulation No.665/2014 concerning the conditions of use of the optional quality term "mountain product"[10].

According to this law, Romania, together with Austria, Bulgaria, France, Italy, Poland, Spain and Switzerland is a country with delimitations and specific mountain law.

Also, this law stipulates that for setting up the strategies for the development and protection of the mountain area, a National Agency of the Mountain Area was established. This agency has regional centers of mountain development and also offices of mountain development at the basins level.

For each group of mountains there were established Committees of Massifs with a consultative role at the territorial level, and also the National Council of the Mountain which is also a consultative body with the task to assure the link between the Romanian Government and the representatives of the mountain areas regarding the strategies and policies specific to the area.

Order No. 174/2021 of the MARD defines the mountain product as "a product achieved of raw materials provided by the mountain areas, the forages for animal nutrition also come from the mountain regions and the processed products are made in the mountain areas and destined to human consumption" [29].

**Specific objectives for the sustainable development of the mountain areas**

As provided by the Mountain Law and National Program of Rural Development 2021-2027, there are important objectives of the future strategy and measures which have to be taken in order to continue the sustainable and inclusive development of the mountain regions by sustaining mountain economy so that the local population to be involved in the specific economic activities, which preserve traditions, cultural identity and heritage, maintain biodiversity and the beauty of the landscapes, increase the attractiveness of the regions and life quality.

-First of all the improvement of infrastructure: roads, ways of communication, dwellings etc, water supply, sewerage collection and use, waste management, assuring electricity and gas, internet access and phone communication network in broadband, work digitalization, facilities for the access to education by rehabilitating the schools and gymnasiums, creating medical and sanitary points, consolidation of the infrastructure which has to assure protection against erosion, landslides, floods; also, irrigation systems for agriculture, water drainage systems, improvement of sport and leisure infrastructure, investments in isolated chalets, ski slopes etc.

-Identification of the economic activities which have to stimulate young people to develop entrepreneurship by creating vocational schools, training and extension centers profiled on mountain economy, new jobs.

-For farmers, there are provided facilities for grazing and transhumance, differentiated payments depending on the altitude difficulties in the mountain areas, subsidies for investments for modernizing the farms, credits with low interest rate, endowments for centers for animal reproduction and selection, improvement of the animal production potential, organizing fears and exhibitions locally.

-Stimulating the creation of associative forms like associations and cooperatives in order to assure the needed inputs, to increase production, and better promote the mountain products, facilities for improving grasslands and their productivity, creating centers for collecting, processing milk, meat, wool, wood etc, storage of the products, and certification for the "mountain products", "traditional product" and "organic products".

-Special measures are destined to encourage the young farmers who grow more than 5 LU (livestock units) will be exempted to pay the taxes for a period of 5 years and 50% of incomes for the next period. The young people will benefit of training, advising, and vocational training.

-Tourism will be encouraged by facilities to improve the access to tourist destinations, to enlarge the accommodation capacity and facilities and improve service quality, to restore the historical heritage.

- The specialists, doctors and professors who would apply to work for minimum 5 years in the mountain areas will benefit of an installation premium and financial aid to buy a dwelling.

-Diversification of the local economy by creating new jobs for collecting forest fruits, medicinal plants, mushrooms, tourism, agro-tourism and eco-tourism facilities, traditional handicrafts, medical, social, sanitary-veterinary, trade, transport, information technology, energy services etc.

-The promotion of the local mountain products has to be intensified to sustain the small and medium business, specific to processing industry and services.

-The urban mountain area will be encouraged to make innovations and restorations for improving the attractiveness of the sceneries, villages, houses, gardens, historical and cultural places. Also, local markets where the local producers to sell their mountain products will also be organized.

- Valorizing the natural and cultural heritage of the villages, preserving the local traditional architecture, art and traditions, cultural and natural heritage and creating centers for tourism promotion and promotion of mountain traditional values.

-Diversifying the mountain products and their commercialization as „mountain products", "traditional products" and "organic products" using short supply chain.

- Compensatory payments will be allotted for mountain areas facing natural or specific constrains.

-Promoting the extensive agricultural practices with reduce impact for environment by agri-environment payments and organic farming for ensuring environment protection and biodiversity preservation

- Increasing the attractiveness of mountain area by creating local brands.

-Encouraging the initiatives based on innovation and cooperation

-In the field of forestry, it is provided afforestation, a better use of forests, measures for forest protection, support for planting new forest, preservation of the indigenous species, expanding the forest with protection role, taking prevention measures against natural damages, improvement of wood management.

-To improve the living standard of the local population, in the mountain areas will be created new jobs by the diversification of the activities, with a deep impact on income sources, reduction of taxes and payments for young people will contribute to the reduction of their migration to cities.

To assure the sustainable development of the mountain areas it is needed to gather all the forces, initiatives, good practices and to spread them in the mountain territory.

An essential role in the sustainable development of the mountain areas in Romania will have the Center of Mountain Economy in Vatra Dornei, where the last results obtained in the scientific research will be disseminated in practice for improving the productivity of the mountain farms, for improving their competitiveness and diminishing the effects of the climate change and for offering more natural and healthy mountain products to consumers and contributing to food safety and security. Within the training center it will be organized training courses for enabling the local population to develop small business and be aware of its role in the development of the communities to which they belong.

Mountains should become an inexhaustible and renewable resource of water, food, energy by carbon absorption.

In this respect, the XIIth European Mountain Convention Euromontana, co-organized with Cia-Agricoltori Italiani in Camigliatello, Sila National Park, Calabria, Italy on October 25-27, 2022 had the topic “Smart mountains: how to make our territories attractive and future-oriented?” and on this occasion there were made recommendations and launched the ideas to build "Smart Mountain for 2050" [44].

## CONCLUSIONS

The mountain areas have surpass the challenges regarding the depopulation, migration of the young people, the decline in animal livestock, low income and living standard of the residents by a new vision and strategy which has to ensure the sustainable development of the mountainous regions.

Mountain economy has be strengthen and offer stability to rural population and a decent living, a high and effective valorization of the natural and human resources and cultural heritage, at the same time ensuring the biodiversity preservation and environment protection.

Mountain products have to be promoted due to their special qualities which sustain life and meet the best consumers' preferences for natural and healthy products.

The extend of organic farming in the mountain areas will satisfy the market requirements with high quality products.

The engine of the mountain economy is animal farming where investments are required and viable solutions for improving grasslands productivity, animal production potential, the range of mountain products, their marketing, maintaining the local traditions, environment quality and improving the living standard of the local population.

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# CEREALS PRODUCTION AND PRICE IN THE EUROPEAN UNION

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***Abstract***

*The paper aimed to analyze cereals production and price at farm gate, also farm inputs prices (seeds, fertilizers, plant protection products, fuel and herbicides) in the EU in the period 2016-2021 and also partially in 2022 in order to identify the trends in the main cereals producing countries France, Germany, Poland, Romania, Italy, Spain and Hungary and to propose a few alternatives to farmers how to adapt to climate change for sustaining production. Eurostat data regarding cereals production and price at farm gate and also prices for farm inputs were used, graphically illustrated including trend regression equation and coefficient of determination. The results pointed out that EU cereals output accounted for 272.6 million tonnes in 2022, being by -8.2% lower than the peak of 2019. Wheat and maize production is 128.19 million tonnes and, respectively, 55.1 million tonnes, meaning lower levels than before. Cereals output declined in the main producing countries: France, Germany, Romania, Spain, Italy, Hungary, but increased in Poland. High temperatures, heat waves, severe and long droughts, low precipitations were the main causes related to climate change. Cereals price at the farm gate increased, and also production costs went up due to the raise in farm input prices which started since 2021 and exploded in 2022. High price for diesel, seeds, fertilizers, plant protection products, herbicides, were recorded compared to their levels in 2015. The highest increase of producer's price ranged between +60.7% in Hungary and +31.8% in Spain. In Romania it was +40%. Compared to 2015, in 2021, the growth rate of farm inputs price was: +15.8% for diesel, +10.8% for seeds, +9.8% for fertilizers, +5,13% for herbicides and +3% for plant protection products. In the future, farmers have to increase production rethinking cereals structure, using more high potential varieties and hybrids, resistant to drought, diseases and pests; to extend biodiversity and use crop rotation to preserve soil nutrients; to implement technologies with fewer inputs and conservative agriculture for assuring the sustainable development of cereals production, protecting environment and preserving biodiversity.*

**Key words:** *cereals production, climate change, producer's price, farm input prices, European Union*

## INTRODUCTION

Cereals are very important at the global level to sustain population and farm animals life, and also for biofuel [27].
Wheat, maize and rice are the main three cereals cultivated due to their important role in human diet, but also in animal feeding.
Climate change has a more and more negative impact from a year to another, affecting cereals production and not only on large surfaces.
To protect environment against pollution (air, water, soil), agricultural systems and ecosystems have to reconcile N inputs to not exceed the imposed thresholds and improve N management to diminish gas emissions and sustain a more efficient use of N by crops [49].
Due to global warming, cereals production was diminished and the FAO's forecast regarding the world cereals' output had to be reconsidered in the year 2022 and estimated at 2,764 million tonnes, of which wheat is expected to reach 783.8 million tonnes [20].

Europe is a large user and importer of grains, pulses and oilseeds. The EU cereals farming has been deeply influenced in a negative sense by the global warming and the terrible unfavourable weather conditions in the recent years, mainly in 2020, 2021 and more intensively in 2022.

While agricultural sector was facing higher costs and prices and supply shortfalls to the unfavourable weather conditions, the demand for cereals remained high [3].

Cereals business has come into a risky and uncertain situation concerning the production costs as a consequence of higher prices for farm inputs which started from 2021 fall and the situation was amplified by the conflict between Russia and Ukraine which increased fuel and energy prices with a negative effect on all the other prices in the economy.

The European Parliament has made the recent assessments which confirm a diminished cereals production in the EU main producing countries due to the extreme meteorological phenomena, mainly concerning high temperatures, heat waves and long and serious droughts [12, 8].

The surface cultivated with cereals dropped below the five-year average and production is expected to decrease significantly [6].

More than never before, scientific research is called to look for solutions to the big problems of agriculture in the actual critical context facing energy crisis, farm inputs crisis, price crisis, food crisis and health crisis, when agriculture needs to be helped to assure food for the global population [23].

Comparatively analyzing the EU safety net policies, alternative transparent, predictable and fair solutions could be helpful to reduce farm income downside risks on an EU countries [2].

Diversification of crop structure, taking into consideration old cereals forgotten for years, resistant to drought, diseases and pests could be an alternative. For example, *Triticale* should be an option in some areas where wheat cannot resists to extreme temperatures and dryness and research is called to offer cultivars and hybrids of high productivity and also resistant to drought, diseases and pests [50].

Another example is *Sorghum bicolor* which could be cultivated for its grains, and used in food for humans, animal feed and ethanol production. Therefore, it could replace a part of cereals like wheat for humans and animals, and also a part of maize for animal feeding and in ethanol production [37, 38, 40, 42].

Farmers have to decide on what surfaces these crops could be cultivated and what new technologies could be implemented and estimate yields and production costs [20].

Biodiversity should be extended and improved to help the farmers to increase efficiency in cereals production, but not only!

Despite that monoculture enabled farmers to use machinery, increasing the efficiency in planting and harvesting, it has become a controversial subject in today's agriculture. Policulture have many advantages among which could be mentioned: erosion limitation, a better storage of carbon into the soil, reduced nitrogen in water, sustained biodiversity below and above the soil. Therefore, crop rotation is in the benefit of farmers, environment and biodiversity [1, 52].

New technologies with fewer inputs have to be delivered to farmers helping them to optimize costs, sustain production and obtain high quality products and their business to be economically viable. Precision agriculture helps the farmers to apply the latest technology destined to produce food using fewer inputs and natural resources. Also, it allows gene editing, to watch plant development and use crops resistant to diseases and drought. The use of seeds, fertilizers and products for plant protection could be kept under control by precision technologies which are environmental friendly [22].

Conservative agriculture could be an option for crop farming assuring increased yields, with low costs, labor savings, carbon sequestration, healthier soils, improved biodiversity, sustainability. [24, 25, 26].

Green Deal established by the EU Commission emphasizes that the future agriculture has to be more friendly with the environment, and in this respect, organic farming should be practiced on larger surfaces and also new technologies with reduced chemical fertilizers and pesticides or with organic products for sustaining soil fertility, production and product quality are required [39, 45, 46, 47].

In this context, the aim of the paper was to analyze cereals production and price at farm gate, also the farm inputs prices (seeds, fertilizers, plant protection products, fuel and herbicides) in the EU in the period 2016-2021 and also partially in 2022 in order to identify the trends in the main cereals producing countries France, Germany, Poland, Romania, Italy, Spain and Hungary. In the paper there are pointed out the causes of the decline in cereals production related to the negative impact of climate change. Also, the dynamics of cereals price at farm gate and the farm input prices were analyzed in each country. Finally, there were made some proposals how farmers should adapt cereals farming to climate change for sustaining production.

## MATERIALS AND METHODS

The paper is based on a large information collected from various publications like scientific articles, FAO and European Commission reports. Eurostat data base was used for collecting the statistical data.

The main studied indicators have been:

Cereals production at the EU level in the period 2016-2022, and also in the main cereals producing countries: France, Germany, Poland, Romania, Italy, Spain and Hungary.

Suggestive graphical illustration were made to identify the difference in each country from a year to another.

Cereals prices taken into consideration in this study have been expressed in price indices, calculated in comparison with the price level in the year 2015, considered as a fixed basis.

The analysis regards:

-producer's price or price at the delivery at the farm gate;

-farm input prices, concerning: seeds, NPK fertilizers, products for plant protection against diseases, pests and herbicides, fuel.

The analysis is approached both at the EU level, and also in each country from the group mentioned above.

The climate changes in terms of extreme meteorological events was also described to justify why cereals production declined in the EU and in each main producing country.

Also, there are explained the causes why the prices increased during the last years.

Finally, there were given some recommendations to farmers how to reduce the impact of climate change and sustain cereals production.

## RESULTS AND DISCUSSIONS

In the EU, cereals production has a decreasing trend due to the climate change that had a deep impact by means of high temperatures, heat waves, low precipitations, long and strong drought, water shortages which created crop stress and cut the yields not only in case of cereals but also for other plants and in animal sector as well.

These extreme weather phenomena have been more intensive in the years 2020, 2021 and 2022. Compared to the maximum cereals output recorded by the EU in the year 2019 and accounting for 299.36 million tonnes, in the year 2022 the obtained production is 272.6 million tonnes, meaning by 8.24% less. In comparison with the output carried out in the year 2020, 286.5 million tonnes, in 2022 the volume of production was by 4.9% smaller. However, compared to the year 2016 level, the reduction is only 1.8%.

Wheat is the major cereal grown in the EU and it accounts for about 50% of production, and the other half is represented by maize and barley summing one third and finally other cereals like rye and oats [7].

Wheat production decreased from 137.13 million tonnes in the year 2016 to 128.19 million tonnes in 2022, reflecting a loss of 6.52%, but compared to the peak of production achieved in the year 2019, accounting for 139.62 million tonnes, this means by 9.2% less in 2022.

Maize for grains production also declined, in 2022 accounting for 55.10 million tonnes, being by 12.5% lower than in the year 2016, and by 24.8% smaller than in the year 2021, when the EU harvested the highest output, meaning 73.19 million tonnes (Fig. 1).

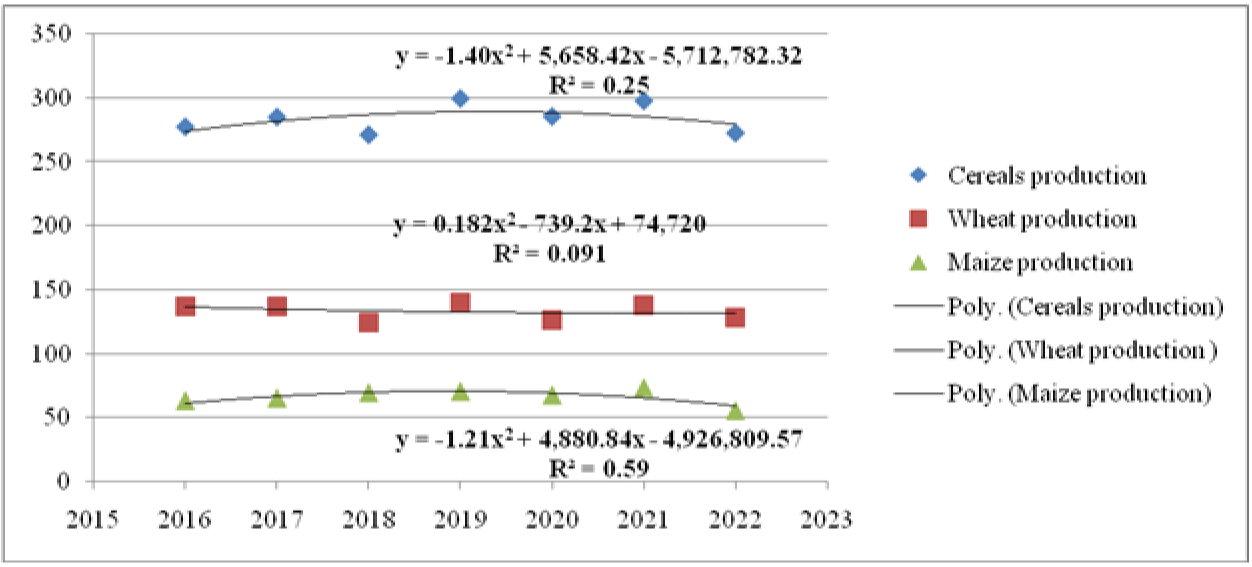



Fig. 1. Dynamics of cereals production, wheat and maize productions in the EU, 2016-2022 (Million tonnes)
Source: Own design and calculations based on the data from [8].

As a consequence, the share of wheat as well as of maize in the EU cereals output declined from 49.4% in 2016 to 47% in 2022 in case of wheat, and from 22.7% to 20.2% for maize.

The main cereals producing countries in the EU are France, Germany, Poland, Spain, Romania, Italy and Hungary and also United Kingdom till Brexit.

The situation of cereals production in these countries in 2022, compared to the peak of output recorded in the year 2019, changed as follows:

- France was facing a decline in cereals output by 14.31% from 71,208 thousand tonnes in 2019 to 61,023 thousand tonnes in 2022.

-Germany registered only 4.13% decrease in cereals output from 44,329 thousand tonnes in 2019 to 42.50 thousand tonnes in 2022.

-Poland is the only EU country that registered a higher cereals production in 2022, accounting for 36,000 thousand tonnes, by 24.18% more than 28,990 thousand tonnes in 2019.

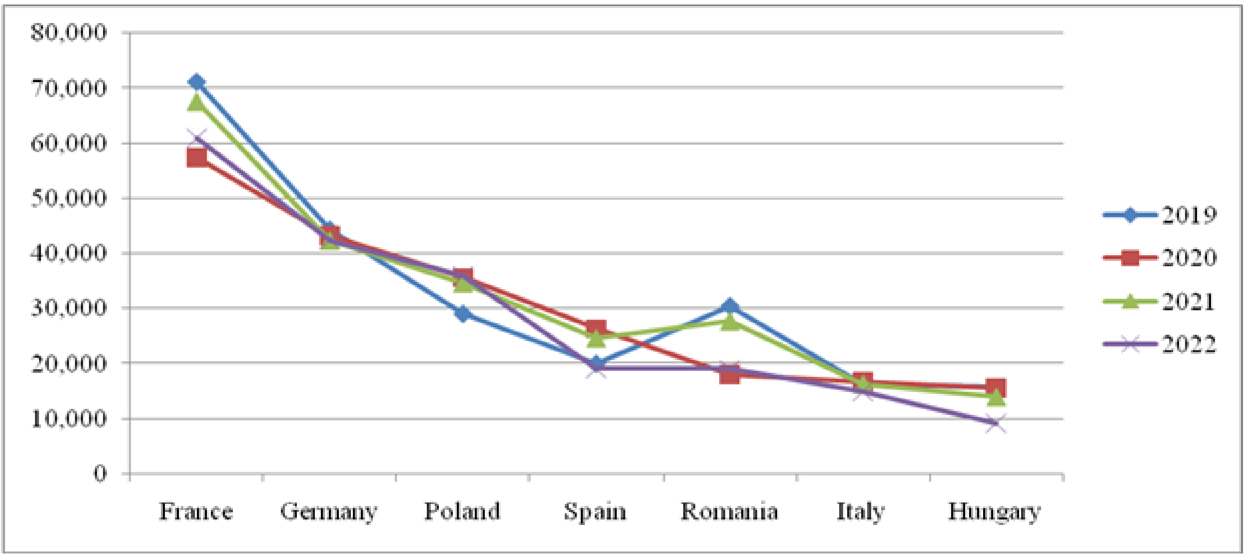



Fig. 2. Dynamics of cereals output in the EU main producing countries, 2019-2022 (Thousand tonnes)
Source: Own design based on the data from [13].

-Spain recorded a production by -4.06% lower in 2022, more exactly 19,133 thousand tonnes, compared to 19,942 thousand tonnes in 2018. But, in comparison with the peak of

26,389 thousand tonnes in the year 2020, this means a loss of 27.5% of grains.

-Romania also was facing a substantial reduction in cereals output. It accounted for -37.07% in 2022, as production level was only 19,140 thousand tonnes compared to the highest production of 30,412 thousand tonnes achieved in 2019.

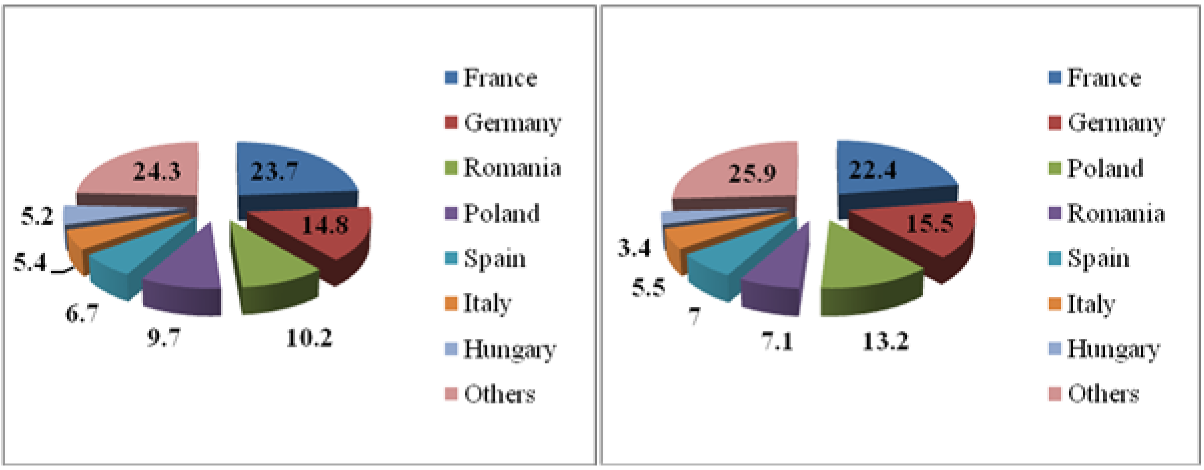
However, Romania is one of the most important cereals producers in the EU. It has a high potential as large surfaces are cultivated with maize, wheat, barley, rye etc., high production performances were recorded in many years, but the last period of time the long droughts caused by high temperatures and low annual precipitations diminished yields and harvests [32, 35, 36, 43 ].

-Italy was another country which obtained lower results. In 2022, it harvested 14,996 thousand tonnes cereals, by -7.05% less than in 2019, when its production was 16,132 thousand tonnes.

-Hungary registered 9,224 thousand tonnes cereals in 2022 by -41.25% less than in 2019, when the grain output accounted for 15,698 thousand tonnes (Fig. 2).

The share of the main producing countries in the EU cereals output in 2022 compared to 2019 is shown in Fig. 3. The figures show that France keeps it top position, followed by Germany. In 2022, Poland passed on the 3rd position, while Romania went down on the 4th one. Spain, Italy and Hungary remained on their places: the 5th, 6th and 7th.

All these countries together contributed by 74.02% to the EU cereals production in 2022.




In 2019 In 2022

Fig. 3. The contribution of the major producing member states to the EU cereals production in 2022 versus 2019 (%)
Source: Own design and calculation based on the data from [13].

**The main weather phenomena which reflected climate change and its negative impact on cereals production**

Climate change have had a more intensive impact on agricultural performance, in the present case, on cereals production.

Some studies on the influence of the climate on cereals production proved the existence of a negative correlation between the high temperatures and yields and a positive relationship between precipitations level and production performance [48].

The extreme weather events in Europe during the last years have been an "alarm bell" regarding the global food security crisis, as long as the European farmers have to struggle to produce and survive.

Wheat and maize next to rice form "the crop trilogy" with the largest importance in assuring the global food.

Europe was facing extreme weather phenomena like: heat waves from Africa, lack of rainfalls, long and severe droughts, even pedological droughts, strong storms as it happened in Italy, France, Spain, Romania in 2022, which could be considered the worst year for agriculture.

The unfavorable weather conditions have been noticed even since winter of the year 2020 which was a mild season with low precipitations level and a low snow layer not able to ensure enough moisture into the soil which did not allow the crops to grow sufficiently especially in their early stages of vegetation.

The spring of 2021 continued with relatively low precipitations and crops continued to suffer during their vegetation period.

The summer continued with a long period of high temperatures and drought and even the autumn season was warm and with low precipitations which caused problems to farmers while they were preparing the land for sowing.

The winter of the year 2021 was again a mild season with low precipitations so that the soil was dried up by water to a depth of about 80-90 cm, a real pedological drought as it happened in a few Eastern and Southern countries so that the farmers had to start sowing for the spring crops in delay.

The 2022 summer was hot and brought several heat waves and the long drought has deeply affected maize for grains, but also sunflower, crops which have been under a continuous stress.

In some regions, the ground cracked, the reserves of water for irrigation were diminished so that the authorities imposed restrictions regarding the use of irrigation water and more than this, in some regions, the rivers, lakes and irrigation canals have dried up and irrigations could not be applied.

The most affected countries have been the Mediterranean ones: Spain, France, Italy, Greece, but also countries from the Eastern part of Europe like Romania and Hungary.

In consequence, the yields were cut and the harvested output was lower than before as the statistics proved [10].

In the EU, the prolonged drought, associated with soil moisture deficit in combination with vegetation stress have led to the decline in agricultural production [9].

**In Italy**, the heat stress, terrible drought and low precipitations reduced the yield per hectare and implicitly the grain harvest. The production of Durum wheat was very much affected, which diminished the deliveries to processing industry which was obliged to import wheat [11, 21, 28].

In Spain and Hungary, extreme heat and drought diminished wheat and barley production, while in Hungary, Romania, France, Italy and Germany, maize for grains was the most affected cereal.

**Poland** had relatively favourable weather conditions which allowed to perform in cereals production and to win its 3rd position as producer after France and Romania [4, 28].

**In France,** the most disturbing extreme meteorological events were heats, the dry summer, strong storms, and huge rains which caused enormous damages to cereal farmers and not only [28].

**In Spain** there were similar meteorological phenomena: high temperatures which led to water shortages, and restrictions for water use were imposed [28].

**In Germany,** the mild spring with low precipitation levels and summer drought has deeply affected maize production which was below the level of the period 2014-2021. Also, other crops have registered yield cuts and this determined the farmers to continue to adapt the crop technologies according to the weather conditions [51].

**In Romania**, it was a huge deficit of water into the soil even since the winter season in 2021 and also in 2022, a few weak rains at the beginning of spring, but not enough, high temperatures starting since June till late in autumn, heat waves, a long and terrible drought, water shortages, which cut the maize yield and also for other crops like sunflower.

In 2022, about 300,000 ha were affected by drought of the 7 million cultivated with cereals.

The decline of cereals production accounts for 15-18% compared to the 2021 level.

There are regions in Romania were the deficit of water is very high like in Dobrogea, Eastern part of the country [5, 31, 32, 33, 43].

**Cereals price and its factors of influence**

As it is unanimously recognized, price at farm gate is influenced by production costs whose level depends on crop, applied technology, technical endowment, labour.

The variables costs have the highest share in production costs and, besides gross products, they influence gross margin per hectare in vegetal farming [29, 30, 41].

High production potential seeds, especially certified, from high value hybrids, fertilizers (Nitrogen, Phosphorus and Potassium, but especially Nitrogen-based), specific products against crop diseases and pests, herbicides, diesel for machinery (tractors, combines), irrigation water etc are the main farm inputs with the highest share in the variable costs.

The price of each component of variable costs has increased during the last years and especially in the fall of 2021 leading to a higher producer's price. And cereals farming was not bypassed by the increased price of farm inputs.

In addition, cereals price boosted in the year 2022 due to the conflict between Russia and Ukraine, the both countries being major cereals producers.

The inflated diesel price caused a chain reaction determining a higher selling price of all the farm inputs, a high production cost, also increased producer's price and production costs in the milling and bakery industry. In consequence, the price of bread and bakery products also went up affecting the daily basket structure and cost in close relation to consumer purchasing power [44].

The price of fertilizers as well as of plant protection products increased not only due to the inflated prices of raw materials, but also due to energy crisis, mainly regarding gas and electricity costs and also transport costs related to high fuel price [21].

This started from the fall of the year 2021, but the price boom was intensified by the conflict between Russia and Ukraine, so that prices have reached new heights in the 2022 autumn, deepening the cost of living [28].

Besides the negative impact of climate change, which diminished cereals production, but also agricultural output in general, farmers were facing with the price burden and stress, a new attempt that calls into question the future production of the next agricultural year 2022-2023.

Cereals supply and trade has suffered disruptions with a deep impact in providing cereals and other goods to the countries in need.

In this situation, food cost and implicitly food price have exploded resulting a reduction in consumption.

**Cereals average annual price at farm gate in the EU**

Cereals producer's price was deeply influenced by products costs, in their turn depending on farm input prices for certified seeds, NPK fertilizers, herbicides, plant protection products against diseases and pests, fuel and other factors like technologies applied, local soil and climate conditions, farms size, technical endowment, labor force which varied from an EU member state to another and from a region to another.

The analysis of the cereals price indices made in the period 2016-2021 reflected that cereals producer's price increased at the EU level by +37.03% in 2022 compared to the 2015 level considered 100.

The growth of producer's price differs from a country to another as follows: +60.76% in Hungary, +46.69% in Poland, +39.97% in Romania, +37.27% in France, +36.9% in Germany, +34.6% in Italy and +31.85% in Spain. Wheat and maize price has a high volatility linked to demand/offer ratio but also in the context of international markets [34]. (Fig. 4).

**Price indices for seeds** reflected an increase by +10.88% in 2021 compared to price level in the EU in 2015.

If in France, price indices reflected a lower level of the seed price than in 2015, in all the other main cereals producing countries, price indices showed important growths especially in the period 2018-2021, as follows:

-In Romania, the seeds price was lower than in 2015 in the years 2016 and 2017, but in the coming years, it exceeded the 2015 level by: +41.8% in 2018, +34.88% in 2019, +51.04% in 2020 and + 45.71% in 2021.

-In Hungary, also the price indices for seeds were higher than in 2015 by +1.8% in 2018 and up to +16.8% in 2021.

-In Italy, the price indices reflected that seeds price increased compared to its 2015 level, the growths ranging between +1.6% in 2018 up to 14.5% in 2021.

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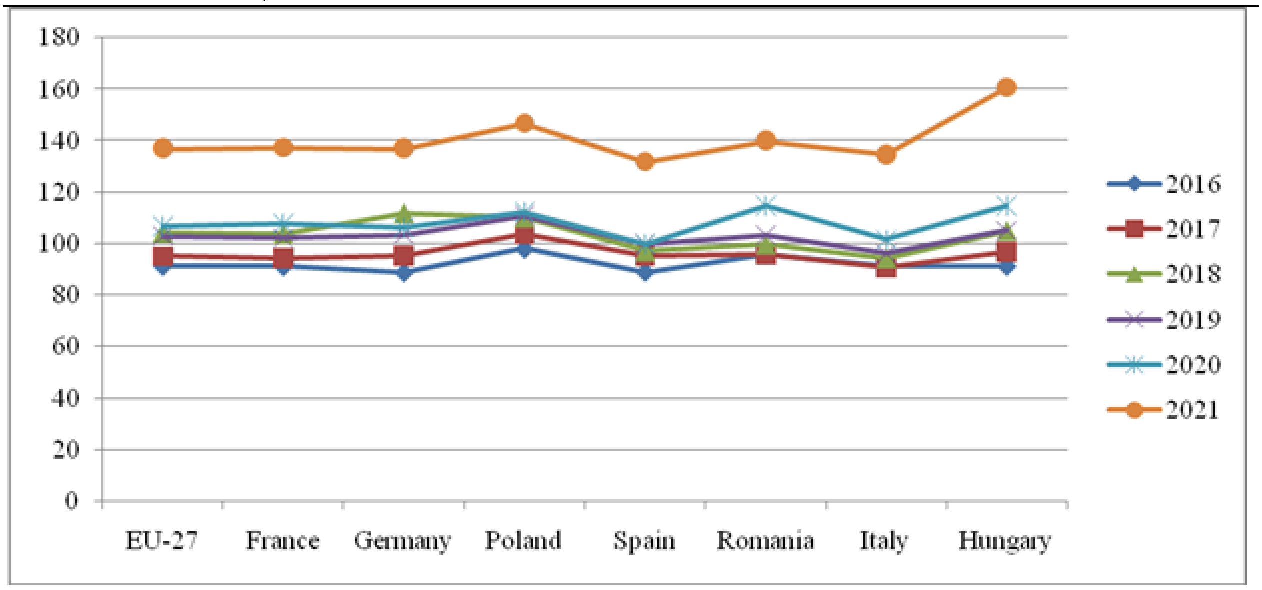


Fig. 4. Cereals price indices in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [14].

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-In Italy, the price indices reflected that seeds price increased compared to its 2015 level, the growths ranging between +1.6% in 2018 up to 14.5% in 2021.

-In Poland, the seeds had a price higher than in the year 2015 starting from the year 2017 by +1.39% and reaching + 12.93% in 2021.

-In Germany, the seeds price indices were smaller than 100 in the interval 2016-2018, but in 2019 and 2020 they reflected that seeds were more expensive by +2.3% in 2019 up to +10.7% in 2021.

-In Spain, compared to 2016, the cereals seeds prices were higher in the whole period 2016-2021 by various percentages varying between +4.3% in 2020 up to 5.9% in 2021.

-In France, in each year of the studied interval, the price indices for seeds were below 100, reflecting no increases compared to their level in 2015 (Fig. 5).

**Price indices for NPK fertilizers** raised at the EU level by +9.87% only in the year 2021 compared to their level in 2015, and in all the other years the fertilizers had lower prices than in the year of reference.

However, in the main cereals producing countries, NPK fertilizer price varied from a country to another as follows:

- In Romania, in 2016, the fertilizers price was below the 2015 level. But, starting since 2017, NPK fertilizers had a higher price which led to a higher production cost. The lowest price growth was +0.57% in the year 2020, but in 2017, the increase accounted for +22.4%, in 2019 for +13.17% and in 2021 for +28.88%.

-In Hungary, the NPK fertilizers price was lower in the period 2016-2020 than in 2015, but in 2021, its level was by +15.6% higher.
-In Poland, the fertilizers price was smaller than in 2015 in the interval 2016-2018, but then it increased in the following three years by +1.22%, +0.58% and +10.7% respectively.
-In Italy, the fertilizers price was higher only in the year 2021 when its growth accounted for +10.3% compared to 2015.
-In Spain, also in the year 2021, the fertilizers price was by +6.2% higher than in 2015.
-In France, in 2021, NPK fertilizers become more expensive than in 2015 by +5.76%, but in all the other years, their price was smaller than in the year of reference (Fig. 6).

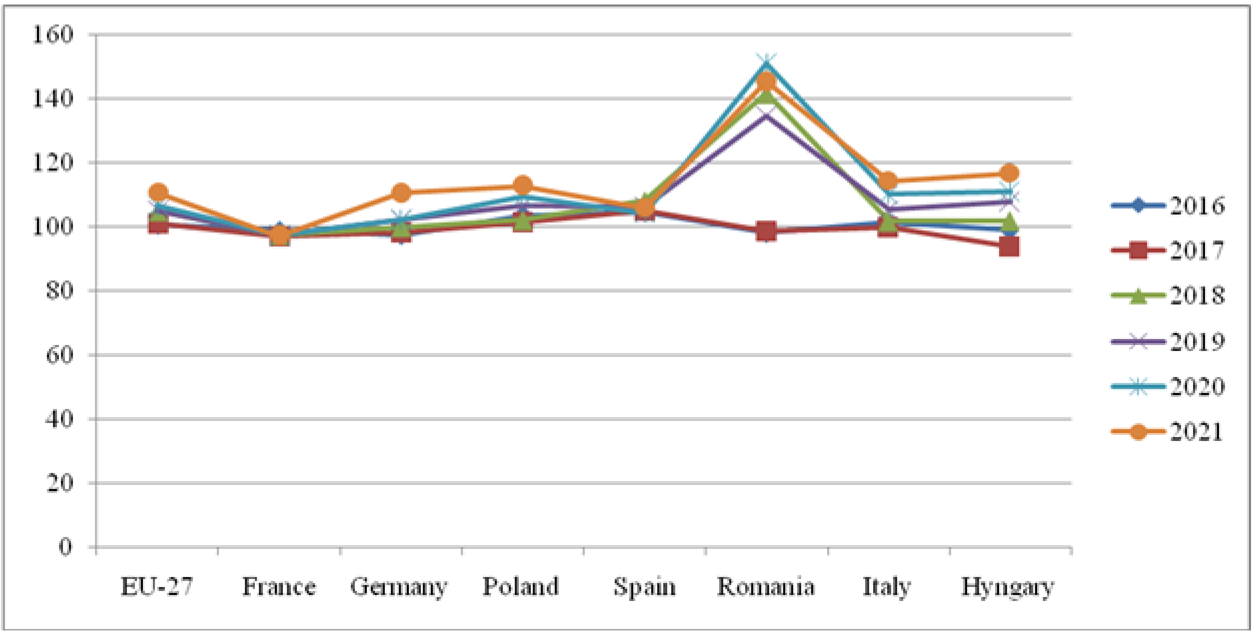


Fig. 5. Price indices of the means of agricultural production, Seeds input (2015 = 100) - annual data in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [15].

**Price indices for plant protection products and pesticides**, compared to their level in 2015, in the next years they reflected higher levels. In the EU, the price growth ranged between +1.14% in 2016 up to +3.12% in 2021.
Price increases were noticed in all the main cereals producing member states, but with different percentages from a country to another.
-In Romania, the growth of the price for plant protection products varied from +14.64% in 2019 up to +43.98% in 2021, versus its level recorded in 2015.
-In Hungary, the lowest price growth accounted for 1.2% in 2016 and the highest one for +15.1% in 2021.
-In Poland, the price registered increases which ranged between 1.22% in 2016 and +11.73% in 2021.
-In Italy, the price of this category of farm inputs registered growths which varied between +2.4% in 2016 up to +11.4% in 2021.
-In Spain, the price was higher by +0.3% in 2016 and up to +7.1% in 2021.
-In Germany, the price for plant protection products registered a higher level than in 2015 by +0.7% in 2016 and up to +7.3% in 2021.
-France is the only country where the price of plant protection products was lower in 2021 compared to its level in 2015 ( Fig. 7).

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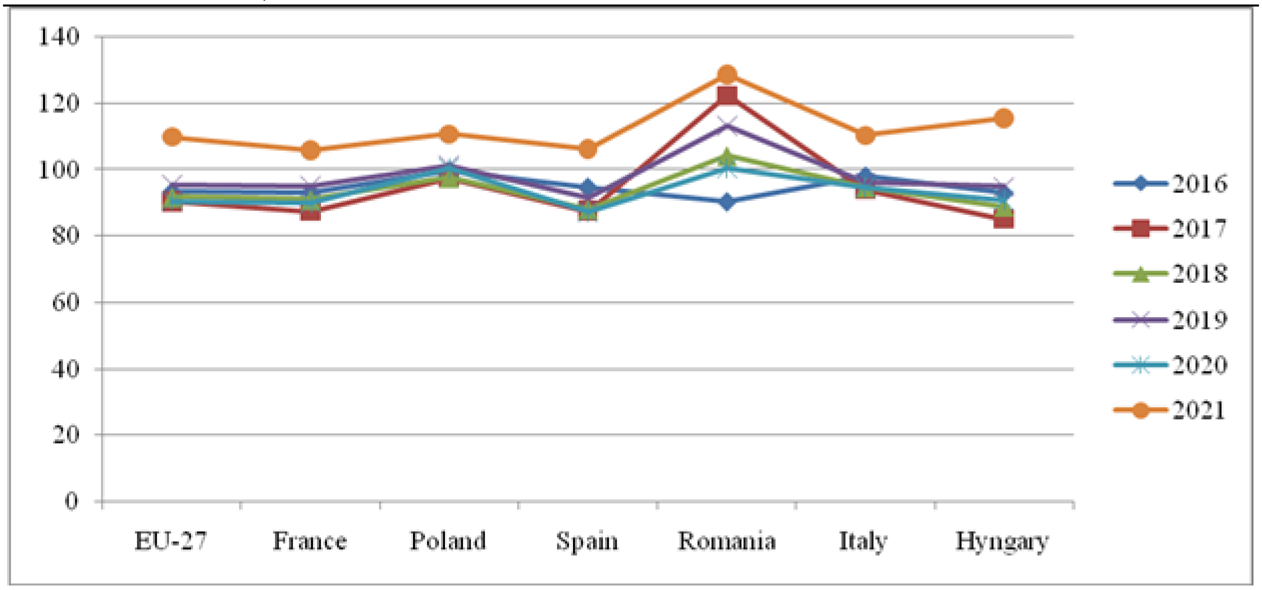


Fig. 6. Price indices of the means of agricultural production, NPK fertilizers input (2015 = 100) - annual data in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [16].

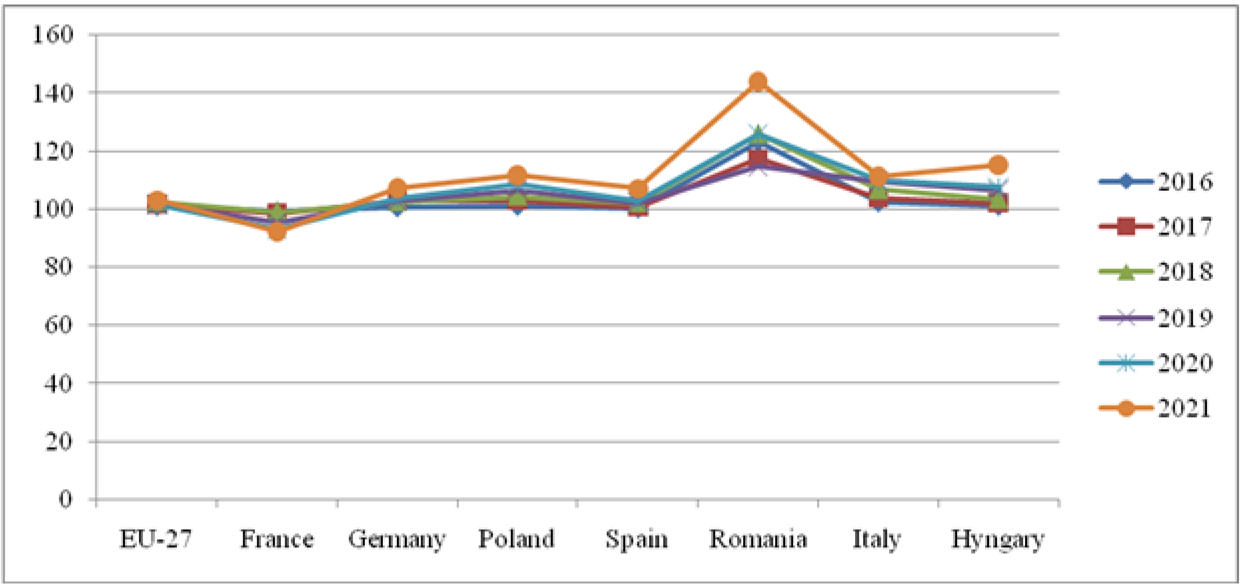


Fig. 7. Price indices of the means of agricultural production, Plant protection products input (2015 = 100) - annual data in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [17].

**Price indices for fuel** exceeded their level in 2015 in the EU, starting from 2018, the growths varying between +12.27 in 2019, +11.96% in 2018 and +15.82% in 2021.
In 2020, the price was smaller than its level in 2015.
The situation of fuel price differs from a country to another.
-In Poland, fuel price was smaller than in 2015 only in the year 2016, but in the coming year, it registered different increases ranging between +2.33% in 2017 up to +24.68% in 2021.
-In Hungary, in the years 2016 and 2017, fuel price was smaller than in 2015, but then, it recorded growths which varied between 2% in 2020 up to +23.8% in 2021.
-In France, except the year s 2016 and 2020, when fuel price was lowers than in 2015, in the other years it raised by +2.26% in 2017, +22.2% in 2018, +20.09% in 2019 and +21.09% in 2021.
-In Germany, the fuel price was below its 2015 level only in 2016, 2017 and 2020. In the other years, it increased by +9.8%, 8.6% and 17.7% respectively.

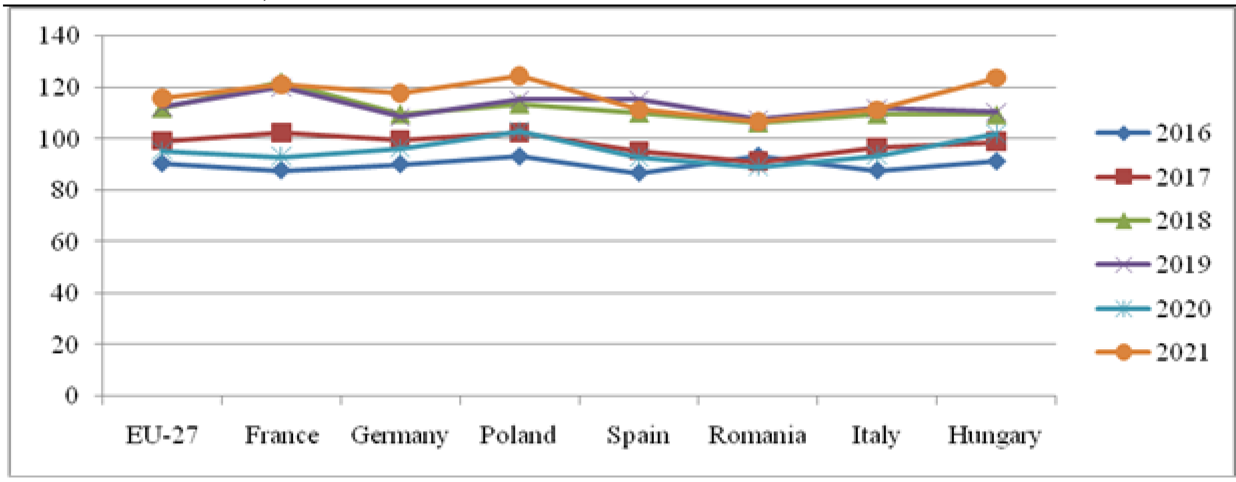


Fig. 8. Price indices of the means of agricultural production, Fuel input (2015 = 100) - annual data in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [18].

-In Spain, also in 2016, 2017 and 2020, the fuel price was below its 2015 record. But, in 2018 it increased by +10.1%, in 2019 by +15.3% and in 2021 by +11.3%.
-In Italy, the fuel price was smaller than in 2015 in the years 2016, 2017 and 2020, but it became by +9.68% higher in 2018, by +9% higher in 2019 and by +11.3% in 2021.
-In Romania, the fuel price increased by 6.25% in 2018, by +7.55% in 2019 and by +6.57% in 2021, but in all the other years it was below its 2015 level ( Fig. 8).
**Price indices for herbicides** increased in the EU by +0.88% in 2016 up to +5.13% in 2021 compared to the year of reference 2015.
-In France, the annual herbicides price in the period 2016-2021 was a little lower than in 2015.
-In Romania, where weeding causes many problems to farmers and the demand of herbicides is high, their price also raised with rates ranging between +1.39% in 2017 up to +55.3% in 2021.
-In Hungary, the growth of herbicides prices varied between +0.8% in 2016 up to +21.3% in 2021.
-In Poland, the growth rate for herbicides prices ranged between +1.5% in 2016 up to +13.3%5 in 2021.
-In Italy, the herbicides were more expensive than in 2015 by a growth rate varying between +1.2% in 2016 up to +9.7% in 2021.
-In Spain, in 2016 and 2017, herbicides had lower prices than in 2015. In the next years, the price increased by rates ranging between +1.2% in 2019 up to +7.5% in 2021 (Fig. 9).

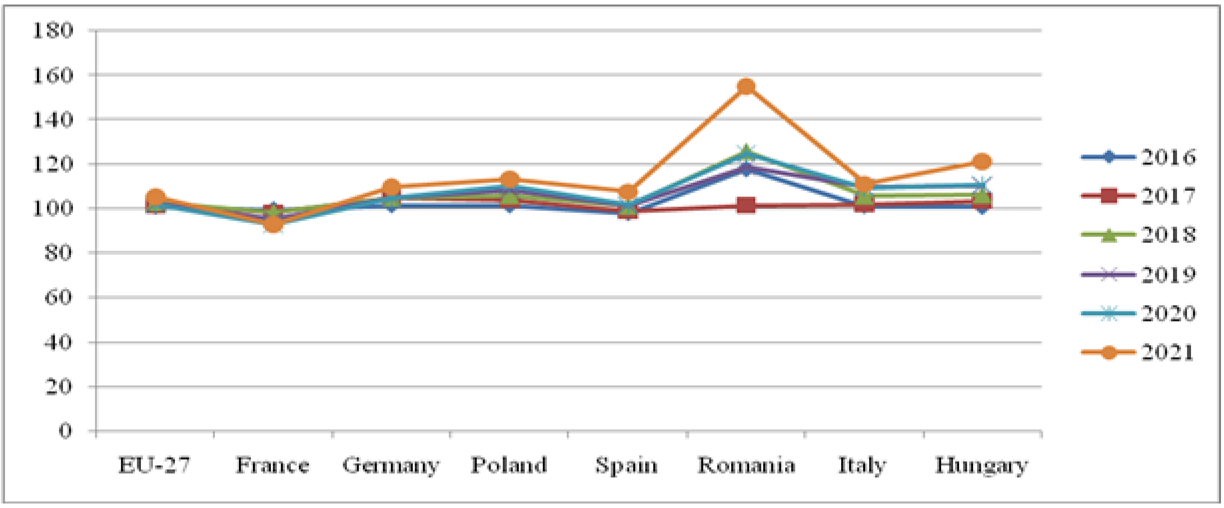


Fig. 9. Price indices of the means of agricultural production, Herbicides input (2015 = 100) - annual data in the EU main producing countries, 2016-2021 (%), 2015=100
Source: Own design based on the data from [19].

## CONCLUSIONS

Cereals production in the EU has registered a decline in the last years as a result of the negative impact of climate change.

The growth of the cereals price is explained by the increase of the production costs determined by the fact that farm inputs have become more costing in the last years and especially in the year 2021.

Cereals price at farm gate increased in almost all the EU member states.

The price of farm inputs raised in almost all the EU countries, but the highest price growth rates were noticed in Romania and Hungary, and smaller growths in the other countries.

The year 2021 is the most critical year characterized by a boom in farm input prices in the EU and the main cereals producing countries.

Compared to 2015, in 2021, the growth rate of farm inputs price was: +15.8% for diesel, +10.8% for seeds, +9.8% for fertilizers, +5,13% for herbicides and +3% for plant protection products.

The year 2022 has amplified prices and production costs in agriculture, cereals farming being included, but also in other economic fields affecting the cost of living.

As price level is difficult to manage by farmers due to the international conjuncture factors, farmers have to be more oriented to the adaptation of their business to diminish the negative effects of climate change.

In this respect, farmers have to be helped by scientific research which have to put at their disposal effective solutions to increase cereals production and grains quality as follows:

-to use new varieties and hybrids of high production potential, resistant to drought, diseases and pests;

-to diversify cereals crops, using much more the ones resistant to drought, diseases and pests;

- to calculate the optimal areas on which the new cereals could be cultivated and estimate yields and production costs;

- to extend biodiversity and preserve soil nutrients by practicing crop rotation and avoiding monoculture;

-to use technologies with fewer inputs which means lower costs, labour saving, environment protection and sustainable development;

-to practice conservative agriculture on larger surfaces for obtaining higher productions and protecting environment.

As mention in Farm to Fork Strategy, and Green Deal, the EU describes that the future belongs to a more sustainable agriculture of high performance called to assure food safety and security and also environment conservation and biodiversity preservation.

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# CEREALS PRODUCTION BETWEEN CLIMATE CHANGE AND PRICE BOOM IN ROMANIA

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***Abstract***

*The purpose of this research work was to analyze cereals cultivated area, yields, production and price at farm gate in Romania during the last decade, 2012-2021 and also in the year 2022 in order to identify the main trends and causes which affected the performances. The data provided by National Institute of Statistics and Eurostat were processed using indices methods, regression equations and r square, and comparisons between maize and wheat. The results emphasized that, compared to 2012 level, in 2021, Romania achieved 27.79 million tonnes cereals (+116.27%), 14.82 million tonnes maize grains (+149.07%), and 10.43 million tonnes wheat (+96.79%). Maize and wheat represent 92.8% of Romania's cereals production. The high record is explained by the large surfaces cultivated with cereals, accounting for 5.35 million ha in 2021 (-1.6% less than in 2012), of which maize 47.6% and wheat 40.6%, all together 88.2%. Yields are still below the levels achieved by France, Germany, Poland, Italy and Spain, which are its EU main competitors in producing cereals. Compared to 2012, in 2021, cereals yield was 5,188 kg/ha (+120%), maize 5,802 kg grains/ha (+166.16%), wheat 4,797 kg/ha (+78.85%), reflecting the efforts made by farmers to increase production. These results were carried out under the impact of intense climate variations and extreme phenomena like: high air temperatures, heat waves, long droughts, low precipitations. High price volatility for Diesel, seeds, fertilizers, products for plant protection etc had a deep impact on the increase of production costs. Cereals price at the farm gate also increased, under the influence of the unbalance demand/supply ratio in the international market, cereals quotations at the international stock exchange, and hostilities between Russia and Ukraine. Un uncertain future is for the coming agricultural years, when farmers have to strengthen their efforts as their business to survive. They have to set up new technological alternatives for crop structure, cultivated areas, amendments, conservative agriculture, lower farms inputs, environmentally friendly solutions to sustain soil fertility, extend biodiversity, and also to keep production costs under strict control and to assure a lower risk for their business.*

***Key words*****:** *cereals production, climate change, producer's price, farm input prices, Romania*

## INTRODUCTION

Romania is one of the most important cereals producers in the EU after France, Germany and Poland [9, 40].
Numerous farms are profiled on cereals cropping being concentrated especially in the South, South East, South Oltenia and West regions of the country [43, 44].
The main cereals cultivated on larger surfaces in Romania are maize and wheat, followed by barley and two-row barley, and rye [46, 47].
High production performances were recorded in many years, but, during the last decade, the long droughts caused by high temperatures and low annual precipitations diminished yields and harvests [32, 35, 36, 43 ] as cereals are very sensitive to long dry periods and lack of water into the soil and in the period of vegetation [49].
These unfavorable weather conditions affected not only Romania, but also many other European countries in the recent years,

mainly in 2019, 2020, 2021 and more intensively in 2022 [1, 30, 8].

The demand/offer ratio is one of the main factors influencing market price, but in case of cereals their price is also impacted by the volatility of the quotations at the international stock exchange, where price index is compiled using the International Grains Council (IGC) Wheat price index of 10 quotations [54].

In addition, farm inputs price has a deep impact on the level of production costs which are also important in establishing producer's price [24].

In the "era of volatility", cost, revenue and profitability have become uncertain and business management is more and more risky, so that for farmers is being more and more difficult to anticipate the expected profits or losses as long as "the prices of farm inputs like: fertilizers, seeds, pesticides, energy, machinery and land raise from a period to another and even from a week or a day to another" [48, 31, 55].

The increase of prices has been intensified since the fall of the year 2021 and has been deeply amplified in February 2022 when the conflict between Russia and Ukraine emerged.

Under these circumstances, when agriculture is facing a mixture of crises regarding: climate change, fuel, fertilizers, seeds, plant protection products, putting on uncertainty agri-food production, market and food security, farmers and researchers are looking for solutions to diminish the negative effects of climate change and to reduce costs in order to help their business to survive [19, 20].

In this context, the goal of the paper was to study the dynamics of the cultivated area, yield, production to identify the main trends in Romania and the comparison with other EU countries was destined to establish our country's position. A special accent was put on cereals price at farm gate, in case of maize and wheat, as a reflection of production costs and profitability level per kilogram of grains. Also, the evolution of the fuel price was studied being considered that diesel price has a deep impact on farm inputs prices (seeds, fertilizers, plant protection products). The identified causes of the production gaps in the analyzed period 2012-2021 and the year 2022 became a starting point to develop a few suggestions to farmers to help them to maintain and increase production under the condition of climate change.

## MATERIALS AND METHODS

The paper was set up using a large range of information sources and statistical data from National Institute of Statistics and Eurostat for the period 2012-2021, and also data about 2022 from Ministry of Agriculture and Rural Development and other sources.

The main aspects approached in this study have been:

-Cultivated area with cereals, at a whole but also by cereal type.

-Maize and wheat yields.

-Cereals, maize and wheat production.

-Maize and wheat price at farm gate.

-Fuel (diesel) price, considered one of the most important cause of the increased price for farm inputs: seeds, fertilizers, products for plant protection etc.

Tables and graphs were used for synthetically illustrate the obtained results which have also been commented.

At the end of the study there were briefly shown the main ideas resulting from this research and there were also presented a few recommendations for farmers to face much better to climate change for sustaining production.

## RESULTS AND DISCUSSIONS

### Cultivated area with cereals

Romania is recognized among the most important cereals producing countries in the EU. Its performance is favored by the geographical position, soil and climate conditions and tradition in cultivating cereals.

In Romania, cereals are cropped on 33% of the cultivated area. However, there are differences regarding the cultivated areas, yields and production among the regions of development and also between the Northern part and the Southern part of Romania [27].

In the last decade, the cultivated area with cereals fluctuated up and down, the general trend being a decreasing one.

In 2021, cereals were cultivated on 5.351 thousand ha, an area by 1.64% smaller than in the year 2012, when it accounted for 5,440 thousand ha. In this interval, after a slight increase from the year 2012 to 2016, a smaller area was cultivated by farmers in the year 2017, taking into account the fact that, in the previous years, yields were very much affected by drought, especially in 2015 when the air temperature was by +1.96$^0$C higher compared to the average temperature during 1961-1990 [29].

From the year 2018, the surface with cereals increased again and culminated with the peak of 5,569 thousand ha in the year 2019, and then again it dropped to 5,338 thousand ha in the year 2020, as the year 2019 was considered by the meteorologists the warmest year since temperatures are measured [29, 49] (Fig. 1).

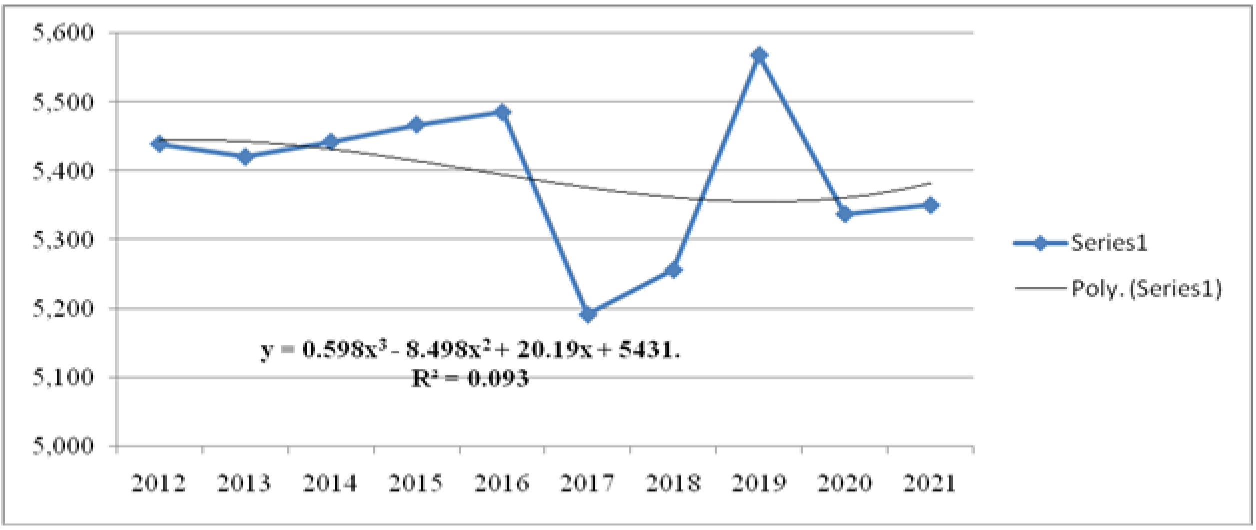


Fig. 1. Dynamics of the cultivated area with cereals in Romania, 2012-2021 (Thousand hectares)
Source: Own design based on the data from [32].

The cereals crops cultivated in the country are: maize for grains, wheat, barley, two-row barley, rye, oats, sorghum and rice.

In 2021 compared to the year 2020, the cultivated area with cereals was 5,237 thousand ha, by 23% smaller [33].

The largest surfaces are covered by maize and wheat.

Maize comes on the top position, but in the studied period, the surface was diminished by -6.7% from 2.73 million ha in the year 2012 to 2.55 million ha in the year 2021.

From this point of view, Romania came on the top position in the EU in the year 2021 [6, 36].

On the 2nd position is wheat, which was cultivated on a larger area from a year to another, and in 2021 it accounted for 2.18 million ha, being by +9.75% higher than in 2012.

For the surface cultivated with wheat in the year 2021, Romania came on the 4th position in the EU after France, Germany and Poland [36].

The surface cultivated with barley increased by +60.9% from 206.9 thousand ha in 2012 to 333 thousand ha in 2021.

Barley and two-row barley registered a diminished cultivated area by -55.2% and respectively -46.6% in the analyzed interval.

Rye was cultivated on much smaller areas, but with a general increasing trend from 8.6 thousand ha in 2012 to 12.1 thousand ha in 2021.

Sorghum registered a decline in cultivated area accounting for -64% from 20 thousand ha in 2012 to 7.3 thousand ha in the year 2021.

Finally, rice was cultivated on a smaller and smaller surface accounting for only 5.4 thousand ha in the year 2021 compared to

11.3 thousand ha in 2012, meaning a reduction by 52.22%.

Therefore, in the cereals crops structure, maize and wheat keep the highest share of 89.3%.

If in 2012, maize represented 50.2% and wheat 36.7%, barley 3.8%, two-row barley 3.9% and the remaining belonged to other cereals, in the year 2021, the weight of these crops was: maize 47.6%, wheat 40.6%, barley 6.2% and two-row barley 2.2%, oats 1.6%, rye 0.2%, sorghum 0.13% and rice 0.11% (Fig. 2).

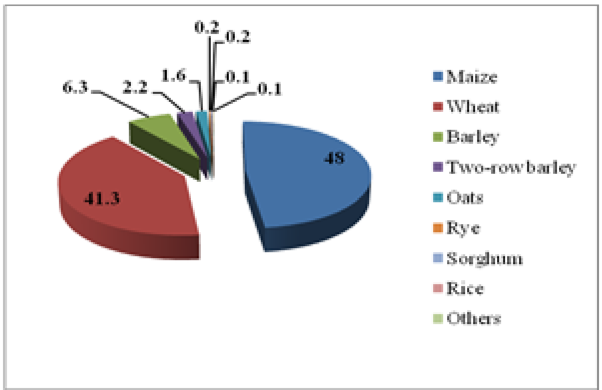


Fig. 2. The share of the cereals crops in the total cultivated areas with cereals in the year 2021 (%)
Source: Own design based on the calculations and [32].

In 2022, the cultivated area with cereals was 5.4 million ha [35].

Taking into account that maize and wheat are the main cereals cultivated in Romania, and in a lower measure barley, in the following paragraphs we discussed especially about these crops [47].

**Yields**

Average production per surface unit depends on many factors, the main ones being: cereal type, variety or hybrid, soil type, fertility and water reserve capacity, availability of irrigations or not, applied technologies and climate favorability.

The last decade proved a more and more intensive influence of weather conditions which were not favorable leading to deviations of yields from crop production potential with damages and losses for farmers' business.

In the analyzed period, average production of cereals varied between 2,357 kg/ha in 2012 and 5,188 kg/ha in 2021, reflecting and increase by +120%. However, the peak of yield accounted for 5,999 kg/ha achieved in the year 2018.

The highest yield increase was registered by maize, +166.14%, as in the year 2021, it was obtained 5,802 kg/ha grains compared to only 2,180 kg/ha in the year 2021.

In case of wheat, the yield growth in the studied interval was smaller in comparison with maize, accounting for only +78.85%, as in 2021, Romania registered 4,797 kg/ha wheat grains versus 2,682 kg in the year 2012.

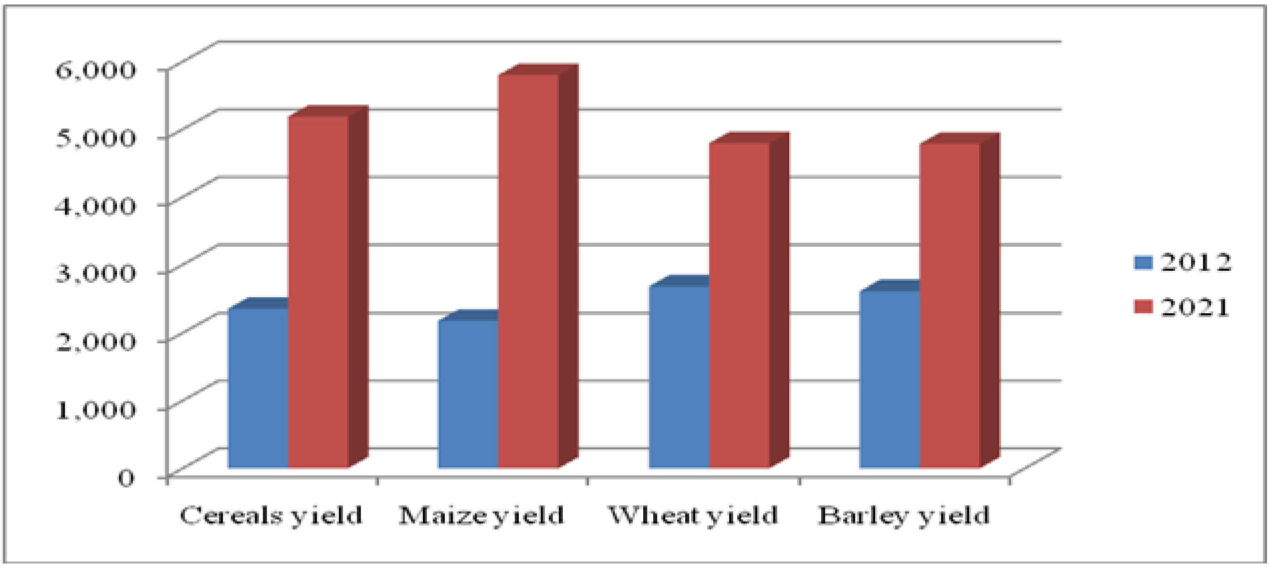


Fig. 3. Cereals, maize, wheat and barley yields in 2021 versus 2012 in Romania (kg/ha)
Source: Own design based on the data from [32].

Despite that it is cultivated on a smaller surface, barley has relatively good yields which must be specified. In 2021, barley yield accounted for 4,786 kg being by +83.16% higher than in 2012, when this crop produced only 2,613 kg ( Figure 3).

In case of cereals yield, in the analyzed interval, the highest performance of 5,999 kg/ha was achieved in the year 2018 compared with the lowest level of 2,357 kg/ha in 2012.

In case of wheat, the most favorable year was 2017 when it was obtained 4,888 grains per ha in comparison with the lowest yield of 2,966 kg per ha carried out in the year 2020, the minimum level in the whole analyzed decade.

In case of maize, the highest yield was 7,644 kg grains per ha achieved in the year 2018 versus the lowest level of 2,180 kg in the year 2012.

Barley was more productive in the year 2021, reaching 4,786 kg/ha compared to the lowest yield of 2,613 kg registered in the year 2012.

The dynamics of cereals yield is shown in Fig. 4 and the dynamics of maize and wheat yield in Romania is presented in Figure 5.

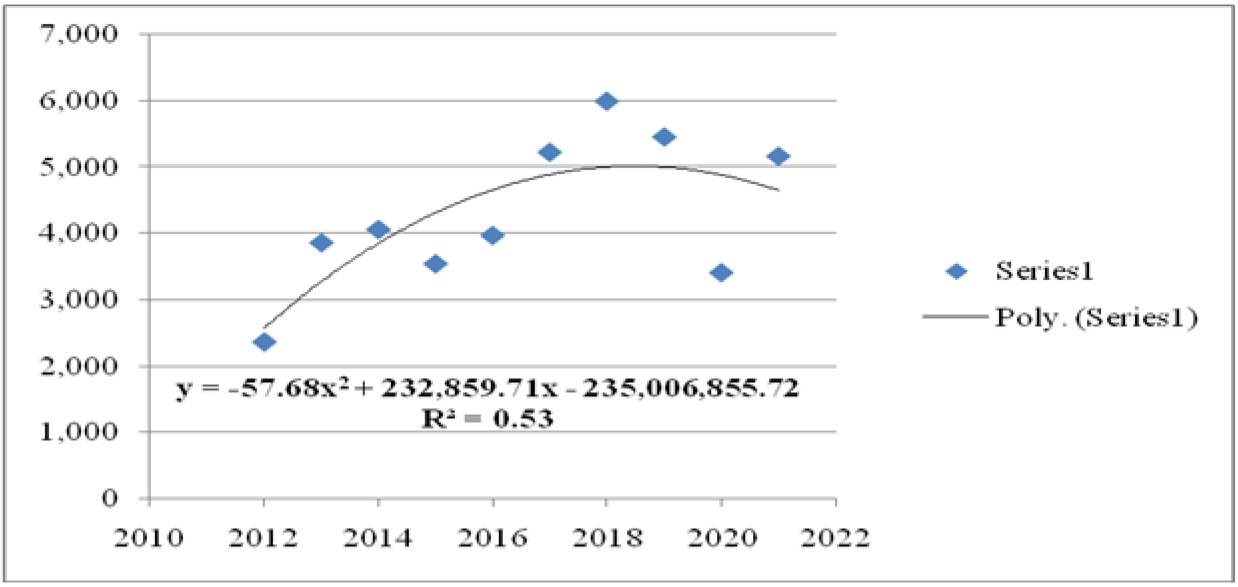


Fig. 4. Dynamics of cereals yield in Romania, 2012-2021 ( kg/ha)
Source: Own design based on the data from [32].

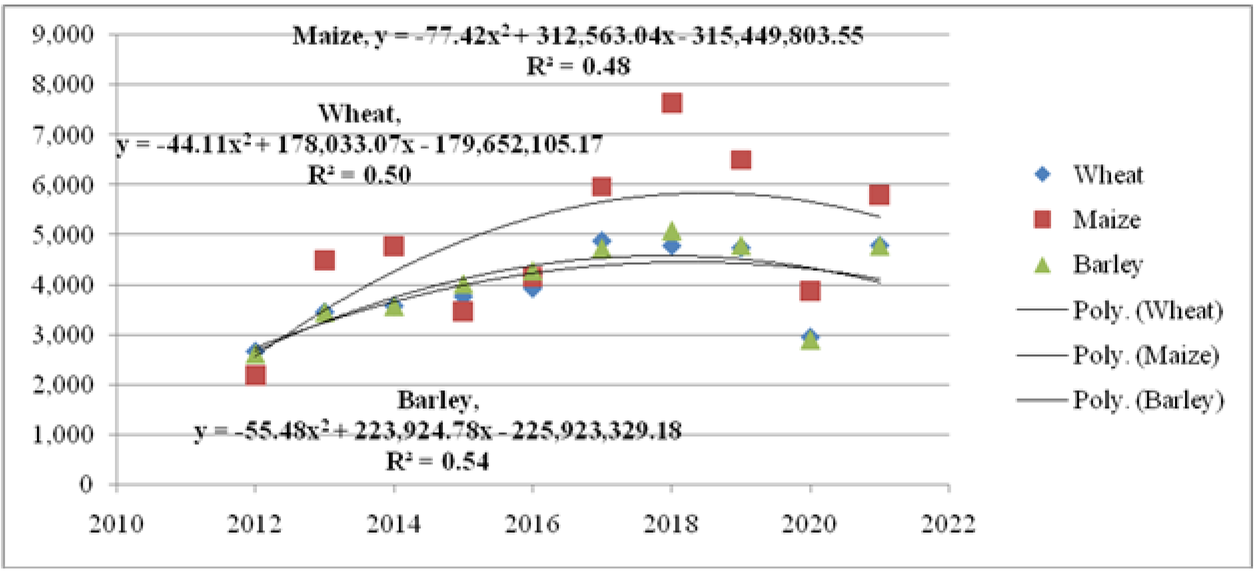


Fig. 5. Dynamics of maize, wheat and barley yield in Romania, 2012-2021 ( kg/ha)
Source: Own design based on the data from [32].

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Having in mind that in this decade the climate change has had a deep impact on yield level, we could consider that Romania achieved a reasonable performance on large surfaces cultivated with cereals.

However the negative impact of bad weather conditions varied from a cereal crop to another regarding if it was about an winter or spring crop, and also on the moments of plant growing from sewing till harvesting.

The extreme meteorological phenomena have intensified their frequency and impact, so that in the last three years 2018, 2020 and 2021 yields and productions were very much affected in many regions of Romania, especially in the South and South Eastern part, in the South Oltenia, West and Moldova.

The low precipitations in autumn when it is the time for sewing winter wheat, barley, and two-row barley, the lack or not sufficient snow layer during winter season, spring with pale rains, and then summer with high temperatures, heat waves, long and strong drought, water shortages have been the most important factors of climate stress on cereals crops, but also on other plants.

From a meteorological point of view, the reality is that the most dried year was 2015 in the interval 2012-2021. In the next years after 2015, yields increased, so that in 2018 there were obtained records for cereals yield, 5.999 kg, and for maize, 7,644 kg, but wheat registered a lower yield than in 2017, when this crop achieved the highest performance of 4,888 kg

In 2022 wheat yield is estimated about 4.3 tonnes/ha, by 25% smaller than in 2021 [34].

In the year 2021, Romania came on the 3rd position after France and Italy for maize yield [6].

Analyzing the production performance per surface unit in Romania compared to the other main cereals producing countries in the EU: France, Germany, Poland, Italy and Spain, we may easily notice that cereals, wheat and maize yields are smaller than in these countries.

Therefore, cereals, wheat and maize outputs of Romania are high due to the larger cultivated areas than in the countries mentioned above (Table 1).

Table 1. Cereals, wheat and maize yields in Romania versus the other main cereals producing countries in the EU in the year 2020 (kg/ha)

| | **Cereals** | **Wheat** | **Maize** |
|---|---|---|---|
| France | 6,384 | 6,680 | 7,935 |
| Germany | 7,130 | 7,819 | 9,587 |
| Poland | 4,705 | 5,239 | 7,076 |
| Italy | 5,627 | 3,925 | 11,268 |
| Spain | 4,502 | 4,253 | 12, 258 |
| **Romania** | 3,453 | 2,966 | 3,977 |
| **-**Diference vs France | -2,931 | -3,714 | -3,958 |
| -Difference vs Germany | -3,677 | -4,853 | -5,610 |
| -Difference vs Poland | -1,252 | -2,273 | -3,099 |
| -Difference vs Italy | -2,174 | -959 | -7,291 |
| -Difference vs Spain | -1,049 | -1,287 | -8,181 |

Source: Own calculation based on the data from [26].

## Cereals production

In 2021, cereals output accounted for 27.29 million tonnes, being by +116.77% higher than in the year 2012, when there were harvested 12.92 million tonnes.

However, in 2018, cereals production achieved its peak of 31.55 million tonnes and also in the year 2019, it reached 30.41 million tonnes. The production differences in 2020 and 2021 have been caused by climate change.

Wheat production recorded its maximum performance in the year 2021, accounting for 10.43 million tonnes, being by +96.43% higher than in 2012.

Maize output accounted for 14.82 million tonnes in 2021, by + 149.07% higher than in the year 2012. But, if we consider the peak of

18.66 million tonnes maize grains achieved in the year 2018, this means that in the year 2021 maize production was by 20.6% smaller (Figure 6). Regarding the contribution of maize and wheat to cereals production, in 2021, maize accounted for 53.3% and wheat for 37.5%, all together meaning 90.8% of total cereals production.

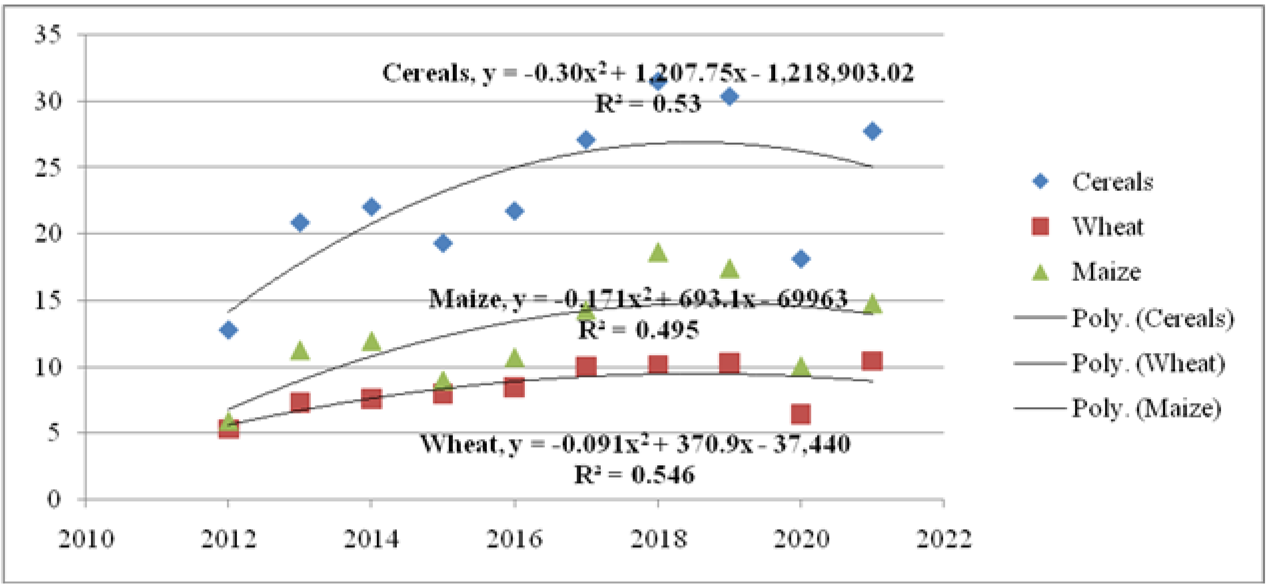


Fig. 6. Dynamics of cereals, maize and wheat production in Ronania, 2012-2021 ( Million tonnes)
Source: Own design based on the data from [32].

The good performances in production registered during the last decade are explained by the efforts made by farmers to improve technologies, more exactly to use certified seeds from varieties and hybrids of high production potential, resistant to drought, diseases and pests, enlarging the irrigated surfaces etc to face much better to the challenges of the climate change.

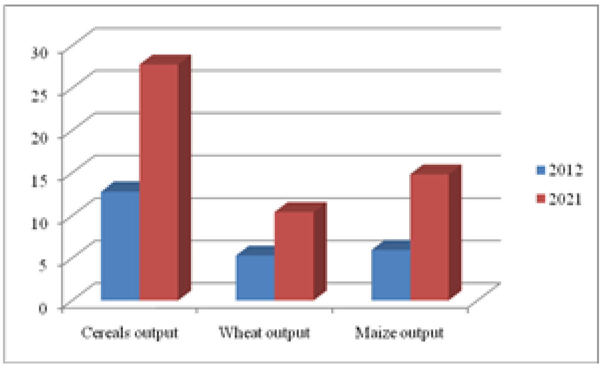


Fig. 7. Cereals, maize and wheat output in 2021 versus 2012 ( Million tonnes)
Source: Own design based on the data from [32].

However, the last year 2019, 2020and 2021 were very stressing for cereals farming, due to the higher and higher temperatures, low precipitations and long drought and pedological drought.

The comparison between the performance in cereals output in 2021 versus 2012 is reflected in Fig. 7.

In the year 2021, Romania was on the 4th position in the EU for cereals production of 27.8 million tonnes, representing 9.3% of the EU cereals output accounting for 297.5 million tonnes.

Romania is a competitive cereals producing country for France which achieved 66.9 million tonnes (22.5%), Germany 42.4 million tonnes (14.3%) and Poland 34 million tonnes (11.4%) [10]. (Fig. 8)

In 2021, Romania came on the top position in the EU for maize production, but on the 4th for wheat production after France, Germany and Poland. But, for the year 2022, the expectations are not similar [36].

Till October 10, 2022, Romania harvested 9.2 million tonnes wheat, representing 88.2% of the level recorded in 2021 and 4.3 million tonnes maize, representing 29% of the production obtained in the year 2021 [5, 35].

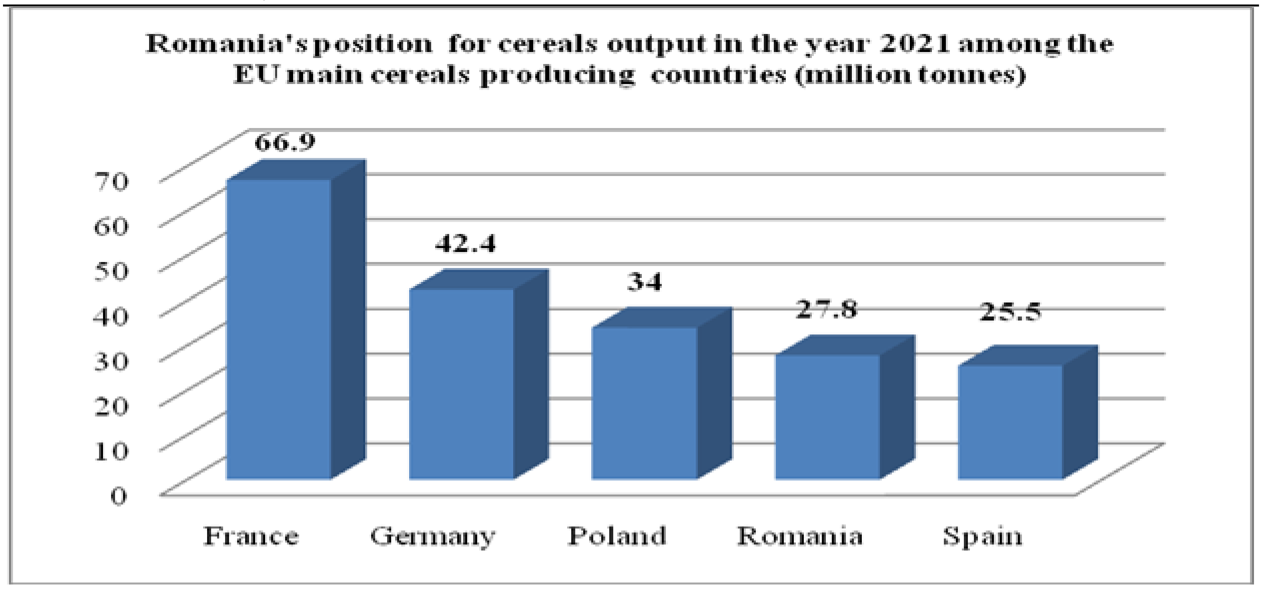


Fig. 8. Romania's position among the EU main cereals producing countries - Cereals output ( Million tonnes)
Source: Own design based on the data from [10].

Till September 2022, a surface of 504,018 ha was affected by drought in 37 counties of Romania. Maize was affected on 149,101 ha, representing (30%) and also autumn wheat and triticale on 189,265 ha (38%), and the remaining belonged to other spring and fall crops.

However, in the year 2022, wheat production is sufficient to cover the domestic need and also to sustain export, while maize output will be able just to assure the internal requirements, and in very small amount export compared to the previous year [3].

**Cereals price at the farm gate**

In the analyzed period cereals price had periods when it remained relatively stable or went up and down, but with slight differences, in close relation to offer and demand ratio for cereals as raw material, international trade and cereals quotations at the stock exchange, and exchange rate, climate change, and other specific factors like the recent hostilities between Russia and Ukraine [28, 24].

***The annual average producer's price***, that is at the farm gate has slightly increased in case of wheat and declined in case of maize in the analyzed decade 2012-2021.

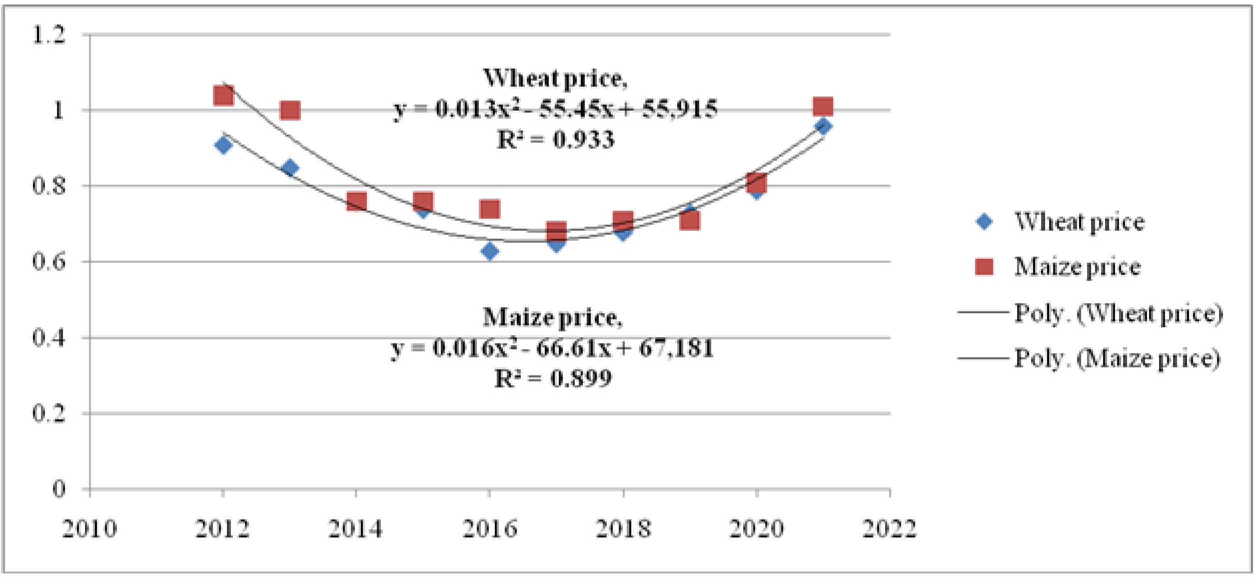


Fig. 9. Variations of annual average wheat and maize price at farm gate, 2012-2021, Romania ( Lei/kg)
Source: Own design based on the data from [32].

In 2021, wheat price at the farm gate was Lei 0.96 per kg, by +5.49% higher than in 2012 and by +21.5% higher than its level in the year 2020.

The maize price accounted for Lei 1.01 per kg in 2021, being by -2.9% smaller than in 2012, but by +24.69% higher than in the year 2020 (Figure 9).

Producer's price varies depending on the pedoclimatic area, farm size, technologies applied, production costs, demand/offer ration and also due to the drought which was more and more longer during the last years. The growth of farm inputs price for seeds, diesel, fertilizers has been noticed even since the year 2020, and become more accentuated in the year 2021, and in 2022, the farmers were facing a real price boom.

Prices have increased not only in Romania, but also in the EU countries and even at the world level. In 2021, the cereals output price raised by an average 28.4%, but by cereal type the growth differed as follows: +34.4% for maize grains and +26.4% for wheat [10].

***The monthly average price for wheat and maize grains at farm gate***

Wheat price, after a relatively long period of small variations between the maximum level of Lei 0.79 in February and April, and the minimum of Lei 0.68 per kg in September 2019, started to increase since the beginning of the year 2020 in the months of April and May, and then in October to December. It continued its growth in the year 2021 in the first six months exceeding Lei 0.9 per kg and then in September it passed over Lei 1 per kg starting from September till December.

In the year 2022, wheat price has exploded since February, after the beginning of the conflict between Russia and Ukraine. It has continuously raised from Lei 1.16 per kg in January to Lei 1.6 per kg, the maximum level, stagnating at Lei 1.59 in May, June, July, August due to the harvest and the transport crises from Ukraine to the importing countries. In September 2022, it reached Lei 1.54 per kg wheat (Figure 10).

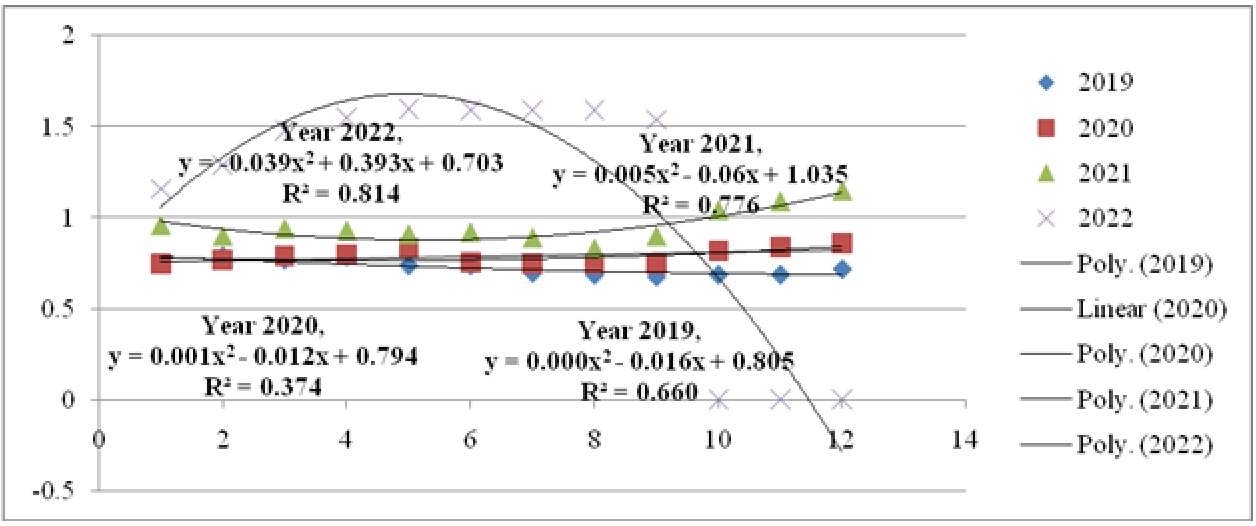


Fig. 10. Monthly average wheat price at farm gate, Romania, 2020-2022 ( Lei/kg)
Source: Own design and calculations based on the data from [32].

The monthly average price at farm gate for maize grains was in general smaller than wheat price, and also in the months of the years 2019, but again in 2020 and 2021 till the month of July, when it equals wheat price of Lei 0.89 per kg and then, maize price exceeds wheat price in August and September, the last period reflecting the loss of production in 2022 due to the long period of drought, high temperatures and heat waves which affected the crop during its period of vegetation.

If in 2019, monthly average maize price varied in general between Lei 0.67 per kg, the highest level in May and July, and Lei 0.6 per kg in October and November, the lowest level, in the year 2020, it ranged between Lei 0.76/kg in December and Lei 0.64/kg in

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February. In the year 2021, the price was Lei 0.8/kg in January and increased reaching the maximum level of Lei 1.02/kg in December. Its growth goes on in the year 2022, reaching a peak of Lei 1.42/kg in July and them it declines in August, accounting for Lei 1.4/kg and in September for Lei 1.37/kg (Figure 11).

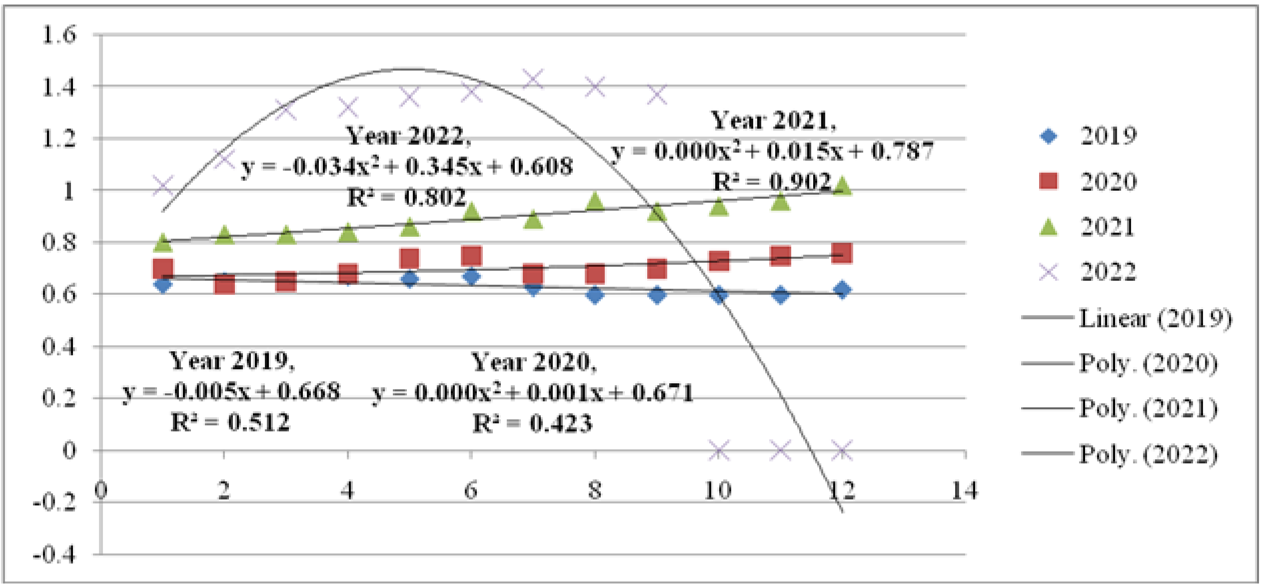


Fig. 11. Monthly average maize price at farm gate, Romania, 2020-2022 ( Lei/kg)
Source: Own design and calculations based on the data from [32].

Compared to cereals price at the farm gate in the year 2015 considered equal to 100, in 2022, price increased at the EU level by +37.03% and in Romania by +39.97%. In other countries, it had different growth rates, its volatility depending on demand/offer ratio but also by the international markets [11, 45].

**The main causes why cereals price increased** are the following ones:

-***The growth of diesel price*** from Lei 5.39 per liter in January 2019 to Lei 5.93 in June 2019, then, a slight decline to Autumn. In 2020, diesel price registered another decrease up to a minimum of Lei 0.47 in May, but since January 2021 it increased to Lei 4.87 and continued this trend reaching Lei 6.42/liter in November and December.

In the year 2022, diesel price continued its ascension reaching a peak of Lei 9.22 per liter in July, and in November declined a little to Lei 8.56 [38, 56]. (Figure 12). The crisis of diesel price is explained by the quotations on the international stock exchange [55].

Also, diesel price increased due to the raise in excise taxes, and according to the fiscal code, the price must be adjusted with the inflation rate, which in Romania reached over 15% at present.

Another cause of the increased diesel price is the conflict between Russia and Ukraine.

However, according to the European Commission, Romania comes on the 9th position regarding diesel price after Bulgaria, France, Hungary, Luxemburg, Malta, Poland, Portugal and Slovenia.

Compared to the 2015 level of fuel price considered equal to 100, in the EU, price indices showed an increase starting from 2018, accounting for +11.96%, then in 2019 for +12.27%, and in 2021 for +15.82%.

In Romania, the fuel price index went up in lower proportions than at the EU level as follows: + 6.25% in 2018, +7.55% in 2019 and +6.57% in 2021 [15].

Diesel price has a deep impact on transportation costs for farm inputs, and also for consumption for the farm machinery for carrying out the agricultural works from land preparation, sewing, fertilization treatments for plant protection ill harvesting.

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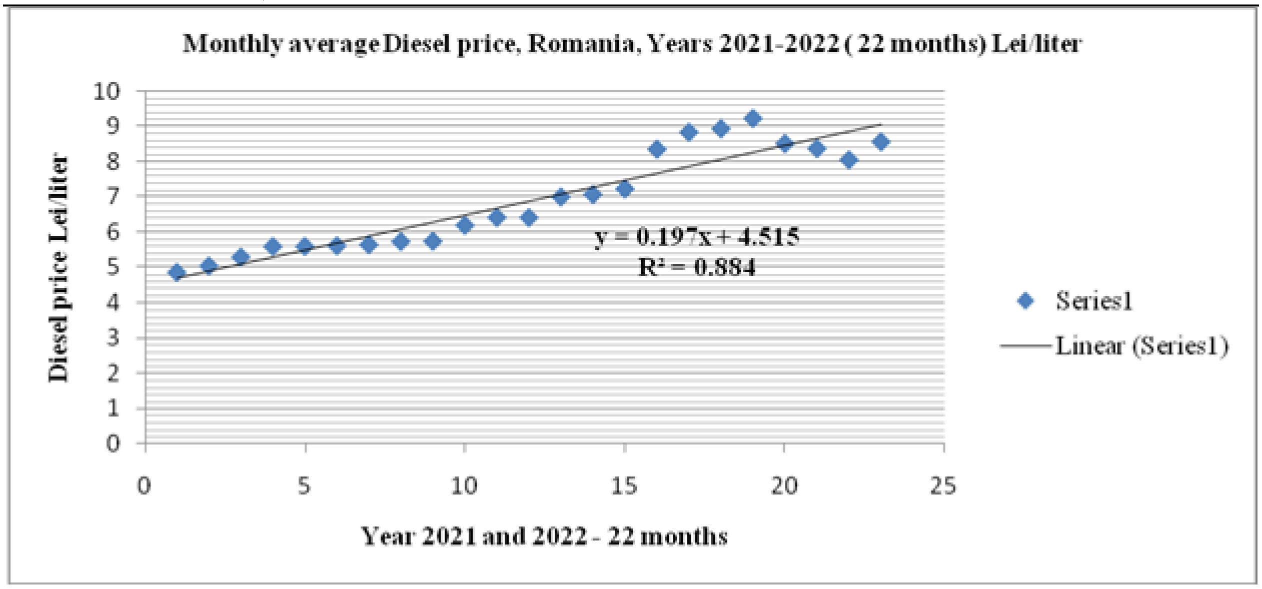


Fig. 12. Monthly average Diesel price - Lei/liter Romania, 2021-2022 ( 22 months)
Source: Own design based on the data from [38].

***-The increase of the market price for certified seeds*** coming from varieties and hybrids of high production potential value, resistant to drought, diseases and pests. Most of the farmers are interested to buy certified seeds as they are obtained in secure conditions and are severely controlled regarding their high genetic and biological value and germination rate which contribute to the increase of production. The high price is a big challenge for farmers, but they need to assure the biological material to produce [17].

Compared to the level of the average seeds price registered in 2015 at the EU level, in the year 2021 it was noticed an increase by +10.88%. But in Romania, seeds price indices level was much higher by: +41.8% in 2018, +34.88% in 2019, +51.04% in 2020 and + 45.71% in 2021 [12].

***-The market price for fertilizers***, especially for Nitrogen-based fertilizers has also increased in close connection to the energy crisis. The process for obtaining fertilizers needs gas which represents 70% of the fertilizers production costs.

At the EU level, taking into consideration the average price of fertilizers in 2015 equal to 100, in the year 2021, NPK fertilizers price raised by +9.87%.

In Romania, starting from the year 2017, NPK fertilizers recorded a higher price by +22.4%, +0.57% in the year 2020, +13.17% in 2019 and +28.88% in 2021 [13].

***-The energy crisis***. Gas price has boosted after the conflict emerged between Russia and Ukraine and the economic sanctions imposed to Russia by the EU countries. Due to this critical situation, the industry producing fertilizers reduced its production and even, in some cases, the companies were closed. Therefore, the demand higher than offer led to a price growth.

At present, the price reached Euro 2,500-3,000/MWh and in this Winter is expected to reach Euro 5,000.

In the coming future, the lack of fertilizers and reduction of their consumption will have a negative impact on the intensive agriculture [25, 37].

***-The increased price for the products for plant protection*** (herbicides, insecticides, pesticides, fungicides) has also went up, due to the price inputs to produces these products.

Compared to the average price at the EU level in the year 2015, considered equal to 100, the price indices for plant protection products were higher in the coming years by +1.14% in 2016 up to +3.12% in 2021.

In Romania, the price growth rate for this category of products ranged between +14.64% in 2019 up to +43.98% in 2021 [14].

Regarding only the herbicides price, compared to the its level in 2015 considered equal to 100, in the EU, herbicides became more expensive by a rate ranging between +0.88% in 2016 up to +5.13% in 2021.

In Romania, herbicides price indices reflected a higher increase varying between +1.39% in 2017 up to +55.3% in 2021 [16]. This is explained by a higher demand of herbicides in this country as

weeding rate is higher than in other EU countries.

**The main causes related to climate change** in terms of meteorological phenomena**,** which affected cereals production in Romania in the period 2012-2021, were the following ones:

- *High temperatures and heat waves* during the vegetation period;

-*Long and severe droughts and pedological drought*.

-*Low precipitation levels* in general and in some regions rare huge and fast rainfalls followed by floods which caused damages to crops, households, humans and animals.

-*A low snow layer or missing* in some regions during the last winters.

In the agricultural year 2021/2022, the air thermal regime during the day exceeded the multiannual averages in the reference period 1991-2020 by +3.6$^0$C. In addition, the low precipitations level in Autumn 2021 has led to a long drought in the most regions of Romania and also in Spring 2022 being installed the pedological drought which affected both the crops sewed in autumn and in spring due to the lack of water soil reserve [1].

The year 2022 has brought a good wheat production, but a smaller maize production, and this was caused in some parts of Romania, like: Dobrogea, Moldova, Oltenia, Banat, Crisana, Transilvania, Maramures and Muntenia. An important decline of production due to drought was noticed on 400 thousand ha, which 201,089 ha cultivated with wheat and triticale and 70,754 ha with maize [2].

-*The hydric stress* caused by the low water reserve into the soil, the drying of water resources.

- *The lack or not sufficient irrigation system* in Romania in many areas where water is needed.

**How farmers have to diminish the impact of climate change in Romania**

Farmers could have a large variety of alternatives which should be used either separately or in a close interrelationship between them for obtaining a higher economic effect as follows:

-To diversify crop structure;

-To adopt multi culture and diminish the share of monoculture for avoiding erosion, nitrogen in water, to store carbon into the soil and sustain biodiversity [4];

-To establish a corresponding cultivated and balanced share of crops;

-To diminish the cultivated area;

-To increase yield using certified seeds from new cultivars and varieties and hybrids of high production potential, and resistant to drought, diseases and pests.

-To establish a rationale crop rotation or amendments [57];

-To implement new technologies friendly with the environment;

-To adopt technologies with fewer inputs in order to reduce production costs and achieve high quality agro-products [19];

-To adopt irrigations to sustain crop production in the regions where water is in deficit (Dobrogea, Moldova etc) [58].

-To quantify yields;

-To calculate and optimize production costs for each crop keeping under control variable costs which have a high impact of production costs and implicitly on gross margin, besides gross product; to select the crops which assure a higher gross margin [38, 39, 41];

-To digitize the farm activities using modern tools for managing crops, production, drought and diseases and pest attack [18];

-To reduce the amount of chemical fertilizers below the imposed threshold by the EU regulations or replace it with bio-fertilizers [50, 51];

-To diminish the amount of pesticides below the imposed threshold imposed by the EU regulations or replace it with bio-products with similar effects [19, 52];

-To apply conservative agriculture which could assure carbon sequestration, less polluted soils, biodiversity preservation, labor savings, lower production costs, a healthier environment and a sustainable development [21, 22, 23].

-To practice organic farming on larger areas [42];

-To implement the measures provided by the EU Green Deal which aims to achieve food security and safety from farm to fork and a healthier environmentally friendly food system and a better life [7, 53].

## CONCLUSIONS

In the analyzed decade 2012-2021, cereals production in Romania increased by +116.27% accounting for 27.79 million tonnes in the year 2021.

Maize is the main cereal crop with the highest contribution to cereals output 53.3% in the year 2021, when its production reached 14.82 million tonnes by 149.07% higher than in 2012.

Wheat comes on the 2nd position with an output of 10.43 million tonnes, the maximum level attained in the studied interval, being by +96.79% higher than in 2012. As a result, the contribution of wheat to cereals production was 39.5% in the year 2021.

Therefore, maize and wheat represent 92.8% of Romania's cereals production.

These high performances are explained by the large areas cultivated with cereals, which in the year 2021 accounted for 5.351 thousand ha, being by 1.6% smaller than in the year 2012. In the cultivated surface with cereals, maize accounts for 47.6% and wheat for 40.6%, all together summing 88.2%.

Regarding the yield level, Romania is far away from the performances achieved by France, Germany, Poland, Italy and Spain, which are its main competitors in producing cereals in the EU.

However, during the last decade, Romanian farmers made substantial efforts to increase cereals yield whose level reached 5,188 kg/ha in the year 2021, being by 120% higher than 2,357 kg/ha in 2012.

In case of maize yield, the growth rate was +166.16%, this crop producing 5,802 kg grains/ha in 2021 compared to only 2.180 kg/ha in the year 2012.

Wheat yield increased in the analyzed interval by +78.85%, attaining 4,797 kg/ha in 2021 compared to only 2,682 kg in the year 2012.

Despite of these performances, production level was much affected by severe meteorological phenomena which during the last decade have been more intense: high air temperatures, heat waves, long droughts, low precipitations.

In addition, irrigation systems operates only on small surfaces and in many farms production depends of the precipitations level.

During the last decade, farmers were facing a huge stress caused not only the impact of climate

change, which obliged them to adapt the applied technologies ever year to the new situations, but also due to the higher and higher prices for farm inputs which have deeply increased production costs making their business a high risk activity.

The prices of Diesel, seeds, fertilizers mainly Nitrogen-based fertilizers, chemical products for plant protection (herbicides, fungicides, insecticides, pesticides) registered an unpredictable volatility in the whole analyzed period, culminating with the price boom emerged by the conflict between Russia and Ukraine which started since February 2022, which produced an unbalanced cereals production and trade.

As a results, production costs increased and cereals price at the farm gate as well, being also influenced both by the unbalance demand/supply ratio in the international market but also by cereals quotations at the international stock exchange.

This critical situation puts cereals production in an uncertain future, as farmers are not able to predict climate and price evolution for the 2022/2023 agricultural year and also in the coming ones.

It is clear that they have to establish new technological alternatives adapted to their local conditions regarding crop structure, cultivated areas, crop rotation, to be more oriented to conservative agriculture, with lower farms inputs and environmentally friendly, to sustain soil fertility and extend biodiversity, to keep production costs under strict control, to assure a lower risk for their business.

Cereals culture has to become a high performance and sustainable activity, protecting environment, preserving biodiversity and assuring food safety and security.

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# EFFICIENCY OF USING HIGH-PROTEIN SUNFLOWER MEAL INSTEAD OF SOYBEAN MEAL IN FEEDING OF GROWING PIGLETS

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***Abstract***

*The article shows the productivity of piglets when they were fed from day 42 to day 70 of this period with sunflower meal (SP-45) instead of soybean meal (SP-48). The manuscript highlights the effectiveness of replacing soybean meal with high-protein sunflower meal in the final period of rearing pigs. It was established that this change in the diet of piglets during their rearing period contributed to a 1.0% improvement in the survival of piglets during the experiment, at the same time it led to a 7.6% decrease in daily feed consumption, which caused a 9.7% deterioration in the intensity of animal growth and as a result of a 6.8% decrease in live weight of piglets at the end of rearing and a 2.3% decrease in feed conversion. The replacement of soybean meal with high-protein sunflower meal in the structure of the starter feed made it possible to reduce its cost by 4.7%, which made it possible to reduce the cost of 1 kg of growth by 2.4%, and the cost of growing 1 head before transfer to fattening by 8.2%. At the same time, in the group of pigs consuming sunflower meal due to a decrease in their productivity and a decrease in their final weight, as a result, the market value of one piglet before transferring them to fattening decreased by 5.9% and the income per 1 reared head decreased by 1.7%. Whereas in the group of piglets that used sunflower meal instead of soybean meal in the starter feed recipe, the profitability of raising piglets was 3.89% higher.*

***Key words*****:** *feeding, rearing, meal, growth intensity, coma costs, cost, profitability*

## INTRODUCTION

Increasing demand for sustainable animal protein and increasing competition for agricultural land for food production make it necessary to search for alternative feed proteins for farm animals [15, 28]. It is known that among the main problems that affect pork production, problems with the fodder base are highlighted [19]. Feeding is one of the main technological factors which influence pig live weight at slaughter and carcass quality [23]. An important issue for pig producers is ensuring that feed meets the animal's nutritional needs, particularly with regard to protein and the correct amino acid composition. Feeding marketable young animals with a balanced diet can be a difficult task not only because of the expensive feed, but also because pigs, as animals with a single-chambered stomach, have a noticeable effect on growth and well-being from the composition of nutrients in their diet.

There are several options to meet the pig's requirement for 100% locally sourced organic ingredients in organic concentrate rations, but when considering practical, economic and environmental concerns, the list of such options is quite short. The list of options varies depending on the climate, with options being more limited in the northern parts of Europe than in the south. In the category of vegetable ingredients, oilseeds and in particular soybean meal of our local production is the most promising alternative to imported soybean flour. But recently, sunflower seeds have become more popular among pork producers as a widely available protein crop [7]. And the ease of processing raw materials further increases the importance of by-products of this crop as a substitute for classic soybean meal [17]. Sunflower seeds (*Helianthus annus*) and by-product meals are important in some parts of the world as a source of high-oil protein material for livestock diets. The main areas of sunflower production in the world today are Argentina, China, Eastern Europe and the United States. Although Australia only produces relatively small amounts of sunflower meal, it remains a valuable source of protein for livestock there [10].

According to the data of foreign scientists [16], sunflower concentrate is a valuable ingredient for pigs due to its high energy concentration and low cost of processing in feed mills. Moreover, it does not contain most of the anti-nutritional factors. However, some authors [14] warn that sunflower products are less digestible than soy products. Although today this view is mixed and, in contrast to it, other authors, on the contrary, note the higher digestibility of sunflower concentrates compared to alternative feeds [27]. Studies of sunflower concentrate for fattening pigs, conducted by domestic scientists, showed that the total amino acid content in it is equivalent to soybean feed. At the same time, the content of methionine in it was 1.5 and 2.1 times higher compared to roasted soybean meal and full-fat soybean meal, respectively. Also, the content of threonine, glycine, cystine, tryptophan, aspartic and glutamic acids in a sample of sunflower meal prevailed over the share of the same amino acids in soy products [25]. In turn, it was established that the additional introduction of only 0.5% of total protein into pig feed contributes to a 1.0% higher livestock survival and 41 g better average daily gains during the fattening period [22]. At the same time, the disadvantages of sunflower concentrates are high sulphur content and low lysine content compared to soybean meal [2]. Solvent-extracted sunflower seed meal has an average crude protein concentration of 30.7% and a high content of methionine [21].

Comprehensive studies of the advantages of sunflower concentrate revealed its versatile effect on indicators of digestibility, growth intensity and quality indicators of pig carcasses at slaughter. According to foreign researchers, the introduction of sunflower concentrate into the diet increased the fat content of fattening pig carcasses [12, 30] and accelerated the gain of live weight of piglets during rearing compared to the use of soybean concentrate [24]. In separate works, this opinion is supported by the argument that the composition of unsaturated fatty acids in sunflower meal caused an increase in the amount of adipose tissue in pigs, especially in the last month before slaughter [1]. There are reports that increasing the amount of sunflower meal in the diet of fattening pigs led to an increase in linear feed intake and to an increase in average daily gains [4]. The addition of sunflower meal to the diet affected the performance of the animals, but not the carcass characteristics. Feed conversion in pigs weighing 30 to 70 kg was improved by its addition [9]. A similar conclusion can be found in other studies, which showed that there were no differences between pigs fed sunflower meal and pigs on conventional feed, except for better values of average daily gains and daily feed consumption. The addition of meal had no significant effect on carcass characteristics [6]. Recent publications of the results of the experimental use of high-protein sunflower fodder prove its positive effect on shortening the rearing period by 1.17 days with a complete replacement of soybean products ($p<0.01$), a significant reduction in feed costs and the absence of a reliable effect on the slaughter quality of pig carcasses [29].

However, other researchers have reported completely opposite results, where pigs fed sunflower concentrate showed slower growth rates and a lower percentage of adipose tissue in their carcasses than their counterparts on classic soy-corn feed ($p<0.05$) [5]. There are also known conclusions about a decrease in feed consumption by young pigs during rearing with an increase in the concentration of protein in sunflower meal, which was added instead of classic feed or in addition to it [10]. Other researchers, on the contrary, point to a significant regression effect ($P<0.05$) on indicators of the following characteristics depending on the share of sunflower meal in the diet. Daily feed consumption, average daily gain, meat content in the carcass and its weight decreased with the increase in the proportion of sunflower meal. During the specified research period, the best results in terms of the amount of feed consumed per day were observed on diets with 20% meal, and in terms of average daily gains, the best results were on diets 5% meal. A diet with 20% sunflower meal had a negative effect on carcass weight [8]. It was also reported that sunflower meal compared to soybean meal, rapeseed meal and especially lupine had the lowest standardized digestibility in pigs ($P < 0.05$) [20].

Thus, taking into account not only the diverse, but often the opposite conclusions of scientists regarding the advantages and disadvantages of using sunflower meal during the period of rearing pigs, the relevance of a more in-depth study of this issue is beyond doubt.

The purpose of our work is to investigate the effectiveness of using high-protein sunflower meal for rearing young pigs in the conditions of an industrial pig complex.

## MATERIALS AND METHODS

The material for the scientific and economic experiment was hybrid pigs obtained from $F_1$ sows of the English Large White breed and English Landrace and boars of the synthetic terminal line PIC-337 of the English genetics company PIC in the conditions of Globinsky Pig Complex LLC, Poltava region, Ukraine.

To conduct the experiment in the spring of 2021, two groups of experimental piglets were formed in the amount of 300 heads each and placed for rearing in separate pens of 150 goals each in accordance with the technology of keeping piglets in the farm. When setting up for rearing, animals in both control and experimental groups were individually weighed and identified with tags of different colors.

During the equalization period from the seventh to the thirty-first day of life, the piglets of both the control and experimental groups received the first pre-starter compound feed traditional for the farm based on soy products. Starting from the 28th and the 31st day, all the experimental piglets were transferred to feeding with the second preaging compound feed, which was fed for 42 days of the piglets' life, after which, for three days, the piglets of both experimental groups were transferred to feeding with the starter compound feed according to the recipe shown in Table 1 whose the nutritional value is presented in Table 2.

Table 1. Composition (%) of compound feed for piglets on growing (41-70 days)

| **Feed components and their nutrition** | **Group I** | **Group II** |
|---|---|---|
| Wheat | 25.00 | 25.00 |
| Barley | 25.81 | 24.66% |
| Corn | 21.52 | 21.00 |
| Soybean meal (48% SP) | 21.17 | 0 |
| Sunflower meal (45% SP) | 0 | 22.3 |
| Soybean oil | 2.00 | 2.12 |
| Lysine sulfate (55%) | 0 | 0.37 |
| L-tryptophan (98%) | 0 | 0.05 |
| Acidifier | 0.50 | 0.50 |
| Premix (TC VPM s/p 4%)[1] | 4.00 | 4.00 |

Source: own calculations.

Pigs of the control group received the traditional combined feed based on soybean products for the farm, and in their analogues from the experimental group, all soybean meal was replaced with sunflower meal "Proglot 45" of the LLC "Potoky", Dnipropetrovsk region, Ukraine. In the main period of the experiment, the animals of the experimental group were given synthetic amino acids in the form of lysine sulfate and L-tryptophan in addition to the main diet for its balancing (Table 1). Animals received such a diet until 70 days of life, after which they were transferred to fattening.

Table 2. Nutrient value of combined feed for piglets during rearing (41-70 days)

| Indicator | Group I | Group II |
|---|---|---|
| Exchange energy of pigs, % | 13.7 | 12.9 |
| Crude protein,% | 17.80 | 17.80 |
| Crude fat, % | 4.10 | 4.10 |
| Crude fiber, % | 3.93 | 5.16 |
| Lysine, % | 1.33 | 1.33 |
| Methionine, % | 0.39 | 0.48 |
| Methionine+Cystine,% | 0.69 | 0.79 |
| Threonine,% | 0.83 | 0.85 |
| Tryptophan, % | 0.21 | 0.21 |
| Valine, % | 0.79 | 0.80 |
| Ca,% | 0.79 | 0.79 |
| P,% | 0.52 | 0.65 |
| P absorbed, % | 0.37 | 0.38 |
| Na, % | 0.19 | 0.18 |
| NaCl, % | 0.50 | 0.51 |
| Vitamin A, thousand iu | 13.00 | 13.00 |
| Vitamin D, thousand iu | 2.00 | 2.00 |
| Vitamin E, Mk/kg | 88.00 | 88.00 |
| Vitamin K, Mk/kg | 3.00 | 3.00 |
| Vitamin B1, Mk/kg | 2.50 | 2.50 |
| Vitamin B2, Mk/kg | 6.00 | 6.00 |
| Vitamin B3, Mk/kg | 20.00 | 20.00 |
| Vitamin B4, Mk/kg | 462.00 | 462.00 |
| Vitamin B5, Mk/kg | 40.00 | 40.00 |
| Vitamin B6, Mk/kg | 4.00 | 4.00 |
| Vitamin B12, Mk/kg | 0.030 | 0.030 |
| Vitamin Bc, Mk/kg | 1.00 | 1.00 |
| Vitamin H, Mk/kg | 0.25 | 0.25 |
| Fe, Mk/kg | 123.70 | 123.70 |
| Cu, Mk/kg | 145.00 | 145.00 |
| Zn, Mk/kg | 131.00 | 131.00 |
| Mn, Mk/kg | 98.00 | 98.00 |
| Co, Mk/kg | 0.45 | 0.45 |
| I, Mk/kg | 2.00 | 2.00 |
| Se, Mk/kg | 0.30 | 0.30 |

Source: own calculations.

When the pigs of each group were transferred to a new compound feed recipe, they were weighed in groups, and when transferred to the starter feed and after the experiment was completed, they were weighed individually.

All experimental piglets were kept in groups of 150 heads in adjacent pens on a partially slotted floor with an area of 0.33 $m^2$ per head. The solid part of the pens, which made up 35% of the floor area of the pens, was heated to the required temperature with the help of warm water. The ventilation of the pigsty was carried out with the help of supply and exhaust fans (Big Dutchman, Denmark) which maintained the necessary temperature, humidity and gas composition of the air through the control processor.

Manure was removed from the premises with the help of a periodic vacuum gravity system.

Fodder was transported to the places where the animals were kept and distributed using the Spotmix II portioned feeding system (Schauer, Germany) which made it possible to prepare a separate compound feed recipe for each pens and take into account its quantity at each distribution to each of them. Dry fodder of the required recipe and in the required quantity was transported to its destination using compressed air, where during its discharge from the pipeline system to the feeder, it was moistened to a specified humidity using special high-pressure nozzles. Animals were fed in portions from metal feeders. The amount of feed in the feeder was supplied depending on the given feeding curves adopted in the farm. The frequency of feeding was adjusted automatically depending on the remaining feed in the feeders, which were monitored by special sensors. After feeding the feed, the final fragment of the feed pipe was flushed with clean water under pressure for four seconds.

During the experiment, in both experimental groups, daily control of the consumption of compound feed was carried out in the section of pens with the help of a feeding system control processor, and it was recorded daily on a paper medium. When pigs were removed from the group, record the date and reason for removal and the weight of the animals removed.

The economic efficiency of feeding the starter compound feed based on sunflower meal "Proglot 45" was calculated based on the data of the accounting information. According to the results of the experiment, calculate the index of fattening qualities using equation:

$$I=A^2/(B \times C)$$

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where:
A – gross growth during the growing period, kg;
B – duration of growing, days;
C – feed consumption per 1 kg of growth.
The obtained results of the experiment were calculated biometrically with the help of Microsoft Office Excel 2010.

## RESULTS AND DISCUSSIONS

It was established that in both experimental groups during the equalization period of feeding in the first four weeks of rearing, during which the pre-starter compound feed traditional for the farm was fed, no significant difference in the dynamics of live weight of piglets of both experimental groups was observed (Fig. 1).

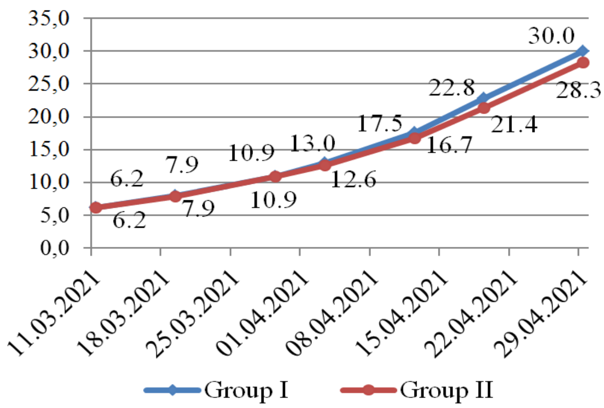


Fig. 1. Dynamics of changes in live weight of piglets during rearing
Source: Own determination.

While at the beginning of the main period of the experiment, the piglets of the experimental group showed lower dynamics of live weight compared to the control group. Thus, on the fifth week of rearing, they had a lower live weight compared to the counterparts of the control group by 0.82 kg, on the sixth by 1.39 kg, and 1.67 kg at the end of rearing. This is caused by the lower growth energy of piglets that consumed compound feed based on high-protein sunflower meal during the experimental period (Table 3).
Piglets of the experimental group for 28 days of the main period of the experiment had 62.1 g ($p<0.001$) lower average daily gains, which caused 1.66 kg ($p<0.001$) lower absolute gains. A decrease in the intensity of growth of piglets of the second group during the main period of the experiment caused a decrease in their live weight at the end of rearing. Thus, it was probably ($p<0.001$) 2.05 kg lower in the group I compared to the group II.
At the same time, in the group of animals that consumed ration feed based on soybean meal, the survival rate of piglets was 1.0% lower compared to their counterparts that consumed a ration based on sunflower meal during this period.

Table 3. Productivity of piglets in rearing with the use of high-protein sunflower meal

| Indicator | Group I | Group II |
|---|---|---|
| The number of piglets at the beginning of the experiment, heads | 300 | 298 |
| Duration of the experiment, days | 28 | 28 |
| The average weight of 1 head of piglets at the beginning of the experiment, kg | 13.00±0.26 | 12.61±0.21 |
| The number of piglets at the end of the experiment, heads | 294 | 295 |
| Preservation of piglets in the experimental period,% | 98.0 | 99.0 |
| Average weight of 1 head at the end of the experiment, kg | 29.95±0.37*** | 27.90±0.35 |
| Weight of weaned piglets, kg | 42 | 49 |
| Gross growth, taking into account animals that have been eliminated, kg | 4947 | 4604 |
| Absolute growth of 1 head, kg | 16.95±0.29*** | 15.29±0.23 |
| Average daily increase, g | 637.7±12.4*** | 575.6±11.6 |
| Feed conversion, kg | 1.66 | 1.70 |
| Daily consumption of feed, kg | 1.06 | 0.98 |
| Index of fattening qualities (I), points | 6.17 | 4.90 |

*** – $P < 0.001$
Source: own calculations.

The introduction of sunflower meal to replace soybean meal in compound feed resulted in a 0.08 kg less average daily consumption of it per head, which, in our opinion, led to a deterioration in the growth intensity of piglets and, as a result, a deterioration in feed conversion by 0.04 kg.

According to the results of the calculation of the complex index of fattening qualities, its value was set lower by 1.27 points in the animals of the experimental group.

Thus, replacing soybean meal (SP-48) with sunflower meal (SP-45) in the diet of piglets during the period of their rearing from 42 to 70 days improved the survival of piglets during the experiment by 1.0%, while at the same time it led to a decrease of 7.6% of daily feed consumption, which caused a 9.7% deterioration in the intensity of animal growth and, as a result, a 6.8% decrease in live weight of piglets at the end of rearing and a 2.3% decrease in feed conversion.

According to the results of the study of the economic effectiveness of replacing soybean meal with sunflower concentrate in the diet of pigs, it was established that the cost of rearing piglets was reduced and its profitability increased. Due to the lower price of high-protein sunflower meal compared to its soybean counterpart, the cost of 1 kg of starter feed in the experimental group was EUR 0.011 lower (Table 4) compared to the control group.

Table 4. Efficiency of rearing piglets in the nursery with the use of high-protein sunflower meal

| Indicator | Group I | Group II |
|---|---|---|
| Cost of starter compound feed in the experiment, EUR | 0.25 | 0.24 |
| Feed cost per 1 kg of growth, EUR | 0.42 | 0.41 |
| The cost of 1 kg of growth at the end of the experiment, EUR | 0.93 | 0.91 |
| The cost of an increase of 1 head, EUR | 11.03 | 9.88 |
| The cost of 1 head of piglets when placing them for rearing, EUR | 20.28 | 20.28 |
| The cost of 1 head of piglets at the end of the experiment, EUR | 31.31 | 30.16 |

Source: own calculations.

This caused, regardless of the lower indicators of growth intensity, the feed cost per 1 kg of growth was lower by EUR 0.010. The operational cost of the increase of piglets during the main period of the experiment also turned out to be EUR 0.02 lower when feeding in the diet of high-protein sunflower meal compared to soybean meal. The lower cost of growth in the animals of the experimental group led to an improvement of EUR1.15 cost of one piglet when it is transferred for fattening.

Thus, replacing soybean meal with high-protein sunflower meal in the ration of piglets from the 42nd to the 70th day of growth made it possible to reduce its cost by 4.7%, which contributed to a 2.4% reduction in the cost of 1 kg of growth, by 10.4% in the cost of growing 1 heads to be transferred for fattening.

Therefore, replacing soybean meal with high-protein sunflower meal in the diet of piglets from the 42nd to the 70th day of growing allowed reducing its cost by 4.7%, which contributed to a 2.4% reduction in the cost of 1 kg of growth, by 8.2% in the cost of growing 1 heads to be transferred for fattening. At the same time, due to a decrease in the productivity of animals and a decrease in their final weight in this group, the market value of one piglet when transferred for fattening decreased by 5.9% and the income per 1 grown head decreased by 1.7%. While the profitability of raising piglets turned out to be 3.89% better in the group of piglets that used sunflower meal instead of soybean meal in the recipe of the starter feed.

It was found that replacing the diet of piglets during their grow-out period with soybean products for high-protein sunflower concentrate resulted in a 7.6% decrease in daily feed intake, which is consistent with other reports [4], which also indicated a decrease in feed intake in parallel with by increasing the content of sunflower meal in the diet. But our data contradict these conclusions [4] about the absence of a decrease in the intensity of growth of pigs with such replacement of protein products. Also, our data contradict the findings [3, 13], which indicate a positive effect of sunflower products on the intensity of growth of pigs. In addition, our findings do not coincide with evidence [18, 5], which indicate no effect of replacing soybean meal with sunflower. Whereas, in our research, 9.7% deterioration in growth intensity was found in pigs whose diet was replaced by soybean meal with sunflower meal, which is consistent with information [11, 26]. Also, in our study, a 2.3% deterioration of feed conversion was found in the experimental group, which is consistent with the findings [9, 26]. Replacing soybean meal with high-protein sunflower meal in our research made it possible to reduce the cost of 1 kg of growth by 2.4%, the cost of growing 1 head before transfer to fattening by 8.2%, and increase the profitability of raising piglets by 3.89%. We consider it expedient to continue research on the impact of high-protein products of sunflower origin on animal productivity and economic indicators of its use.

## CONCLUSIONS

The intensity of growth of piglets during rearing did not differ between groups of animals before the replacement of soybean meal with sunflower meal, while after such replacement, the intensity of growth of piglets fed with sunflower meal decreased.

Replacing soybean meal with high-protein sunflower meal in the composition of the starter compound feed led to a 1.0% improvement in piglet survival and a 7.6% decrease in daily feed intake, which caused a 9.7% decrease in growth intensity and a 2.3% decrease in feed conversion and a decrease of 6.8% in the live weight of piglets at the end of rearing.

The exchange of meal made it possible to reduce its cost by EUR 0.014, which allowed for EUR 0.016 reduce the cost of 1 kg of growth and by EUR 1.15to reduce the cost of growing 1 head before transfer to fattening. At the same time, this replacement caused a decrease of EUR 3.09 of the market value of one piglet when transferred for fattening and EUR 0.32 income per 1 head of piglets during rearing. While the profitability of raising piglets turned out to be 3.89% better in the group of piglets that used sunflower meal instead of soybean meal in the recipe of the starter feed.

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# DEPENDENCE OF THE MICROCLIMATE PARAMETERS OF THE PIG HOUSE ON DIFFERENT FREQUENCY OF MANURE PITS EMPTYING AND OUTDOOR TEMPERATURE

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***Abstract***

*In order to study the dependence of the microclimate indicators in the fattening building on the frequency of drainage of manure pits and the external temperature, an experiment was conducted in the production conditions of the pig complex. Four groups of pigs with 2,500 heads in each group were selected for the experiment. In the first control group, the draining of the manure pits took place before the animals were placed for fattening and as the pits were filled. In the experimental groups, the pits were drained before planting and every 14 days in the second group, every 21 days in the third group, and every 28 days in the fourth group. Gas content and air humidity indicators were measured every third day at 07:00, 13:00 and 18:00 in all four buildings at 6 points in different equally spaced pens of the fattening building under the ventilation valves. It was found that the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying the pits in the building, while the content of carbon dioxide did not depend on it. The content of hydrogen sulfide and ammonia depended on the frequency of emptying manure pits, and the content of carbon dioxide did not depend. At the same time, the content of ammonia and carbon dioxide depended on the external temperature, while the content of hydrogen sulfide did not depend on it. The relative humidity in the fattening building increased with a decrease in the frequency of draining pits, however, it did not depend on the external temperature.*

***Key words***: *ammonia content, hydrogen sulfide, carbon dioxide, humidity, temperature*

## INTRODUCTION

The problem of the latest research on the welfare of pigs have needed to provide a microclimate in the pig house for their comfortable keeping, which is currently achieved in most pig farms due to high energy consumption and over expenditure of resources [46]. Modern sow farrowing facilities have unique microclimate control limitations. The ventilation system must simultaneously meet the thermal needs of farrowing sows and newborn piglets [25, 41]. The microclimate of livestock premises is a set of physical, chemical and biological factors of the external environment that constantly affect animals and technological equipment. The combination of these factors, as well as their impact on the animal body, can be different [17].

Inconsistency of the microclimate parameters with the sanitary and hygienic standards causes in animals a violation of metabolism and reproductive function, a decrease in the body's resistance and productivity, a delay in the growth and development of young animals, and in ensuring high resistance of the body, the creation of an optimal temperature and humidity regime in the piggery is of great importance [16]. Extreme conditions of the microclimate have a negative effect on the body during the embryonic period of development. The high temperature (27–35°C) of the surrounding air during the fertilization period and the first two weeks of growth leads to a sharp decrease in the number of embryos and subsequently in fertility. Under the influence of high temperature, the level of natural resistance and the intensity of carbohydrate metabolism decrease in suckling sows. The blood serum of piglets during the weaning period contains less albumin than globulin fractions [6, 14]. Inconsistency in the main parameters of the microclimate causes in animals a violation of metabolism and reproductive functions, a decrease in body weight gain, feed consumption. Unfavorable conditions of temperature, humidity, air movement and other factors for normal heat transfer cause a violation of the thermal state of the animal organism [2, 12, 38].

Global warming has caused an increase in the incidence of heat stress in recent decades in pigs [40]. One of the parameters for characterizing and classifying the animal farm environment is the temperature comfort range, which reflects the behavior of the animal indoor temperature [7]. High temperature together with high air humidity cause heat stress in pigs. As a result, the production performance of growing and fattening animals deteriorates, and the fertility and milk yield of sows decreases [21, 23]. The air humidity in the building is directly related to the temperature: as the temperature increases, the air humidity, as a rule, decreases, and the lower the air temperature, the lower the animal's body temperature, the slower its recovery. Moisture is released by animals with the released air during evaporation from the surface of the skin, and its amount depends on the live weight. It affects the thermoregulation of the animal's body, and in particular, its heat transfer. The optimal relative humidity of the air in pig houses should be within 60–80%, and the temperature in the building depends on the method of keeping sows and animals for growing and fattening [8, 19]. To prevent overheating in the pig house, it is necessary to establish an optimal air movement system. It is also worth avoiding the formation of drafts, which can overcool the pigs [42]. With a decrease in air flow speed, the probability of the appearance of moisture and exhaust air with an increased concentration of carbon dioxide, ammonia and hydrogen sulfide compounds increases [31, 33]. An excessive amount of these gases indoors leads to breathing problems in pigs, and can even cause pulmonary edema. And the abnormal content of carbon dioxide in the air leads to increased breathing, arrhythmia and even poisoning [35, 45].

It has been established that ammonia, hydrogen sulfide, and carbon dioxide are among the most critical harmful gases for pigs [5, 47], namely their welfare and health [36, 48]. Atmospheric pollution by methane ($CH_4$),nitrous oxide ($N_2O$) and carbon dioxide ($CO_2$), known to account for an average of 81%, 17% and 2% of the total emissions from pig farms, which is 3.87, 0.83 and 0.11 kg $CO_2$ eq. with kg of carcass, respectively [30]. At the same time, the release of harmful gases from vital activities occurs in different ways, which must be taken into account in preventive measures to reduce them. In particular, concentrations of ammonia and carbon dioxide are usually much higher in winter than in summer ($p < 0.05$). Also, in some studies, measurements of gas content showed the highest content in the morning [32], and in others reports [34] at night. When using both "natural" non-mechanized and mechanized closed microclimate systems of negative or uniform pressure, the influence of the seasonality factor of fluctuations in concentrations of harmful gases during changes in the annual dynamics of temperature and wind speeds outside the pigsty is monitored [20, 28, 50]. Many authors report elevated measured concentrations of harmful gases due to factors such as pigs age and body weight, ventilation system features [37], availability of cleaning systems [44], farm location [18], local climate or season of the year [3].

The spread of polluting gases outside the pigsty is an undesirable component of their activity, but it is beyond the bounds of possibility to completely get rid of this phenomenon [11, 26]. Emissions of $NH_3$ and deposition play a critical role in ecosystem acidification and eutrophication and contribute to indirect emissions of $N_2O$ [39]. Methane emissions increase the greenhouse effect [1]. The use of air purifiers to reduce ammonia emissions from production premises in pig industrial complexes is a promising method of the Gothenburg Protocol [13] and other European norms, including the Industrial Emissions Directive [22]. Different types of air purifiers are used to remove ammonia from the exhaust air from piggery premises. Most of them fall into three types: wet scrubbers (also called water-only scrubbers or bio-droplet filter scrubbers), chemical scrubbers and air scrubbers [24]. The use of scrubbers reduced ammonia emissions from pigsty by at least 70%. Similar filters with an efficiency of at least 80% are also used for the decomposition of hydrogen sulfide [15]. Measures to minimize methane emissions also had a positive result, in particular, pig farms using biogasification and acidification had 91% and 93% lower emissions, respectively, than farms without exhaust air treatment [43]. There are also complex solutions that, due to the addition of active chemical compounds to the manure in the manure removal system of the pig house, decompose pollutants into neutral ones and lead to a decrease in their concentrations inside the building and, accordingly, to a decrease in their emissions [49]. There have also been reports that the content of harmful gases decreases with an increase in the frequency of cleaning of manure pits and manure gutters [4]. However, there are directly opposite results, which say that the more often the manure is drained from the pit, the higher the air exchange in it and, as a result, the higher the ammonia content in the pig house [27]. The height of the space above the manure surface in the pit depends on the cleanliness of the drainage of the manure pits. The height of the space above the surface of the manure affects the evaporation and content of ammonia and other gases due to higher diffusion rates and increased air exchange rates in the pit space [10], which increases the content and emissions of these gases.

Thus, taking into account that microclimate systems that do not have special equipment for reducing the concentration of harmful gases, although they satisfy the normal life activity of pigs, but require additional actual scientific research and technical solutions for complete degassing of ammonia, hydrogen sulfide, and carbon dioxide in order to completely purify the air.

The purpose of our research is to study the influence of the frequency of emptying manure pits as a method of reducing the concentrations of harmful gases in the premises of the piggery complex for fattening and determining its influence on microclimate indicators.

## MATERIALS AND METHODS

The study included the determination of microclimate parameters (aeration, humidity, and air temperature) depending on the frequency of emptying of manure pits, the level of their filling with manure, and the ambient temperature. It was carried in the feedlot of LLC "Globinsky Pig Complex", Globinsky district, Poltava region. The experiment was conducted during the autumn-winter period. Four groups of hybrid pigs of Irish origin obtained from crossbred sows of the Large White breed and boars of the MaxGro synthetic line were formed in the amount of 2,500 heads in each group.

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Control group I was put on fattening in building No. 3, where draining of the manure pits was carried out before placing the animals and then partially by ¼ of the volume every 7 days as it was filled with manure.

Experimental group II was fed for fattening in building No. 2, where pits were drained before placing the animals and then every 14 days.

Experimental group III was placed for fattening in building No. 1, where pits were drained before placing the animals and then every 21 days.

Experimental group IV was fed for fattening in building No. 16, where pits were drained before placing the animals and then after 28 days.

Gas content and humidity were measured every third day at 7 a.m., at 1 p.m., and at 6 p.m. in accordance with existing methods in all four buildings at 6 points in different equidistant pens in the building under ventilation valves. A Testo 425m thermal anemometer (Testo AG, Lenzkirch, Germany) was used to determine the air temperature. The content of ammonia ($NH_3$), carbon dioxide ($CO_2$), and hydrogen sulfide ($H_2S$) was determined using the DOZOR-S-M gas analyzer (Testo AG, Lenzkirch, Germany). Air humidity was determined using a Testo 605 thermo-hydrometer (Testo AG, Lenzkirch, Germany) at the level of standing pigs (60 cm).

In addition, on the days of measuring the microclimate, the parameters of the temperature outside the building and the level of filling of the pits were measured.

Animals in all enclosures were kept in buildings measuring 102 by 20 m, in group pens of 50 heads, which were located in four rows, on a completely slotted floor at the rate of 0.75 $m^2$ per pig. The feeding of pigs of all experimental groups was identical, complete and balanced in a multiphase mode, with compound feed of own production. The type of pig feeding was liquid using the WEDA liquid feeding system. Mixing of feed with water in the ratio of 1 part of dry feed to 3 parts of water was carried out in hopper mixers, after which the feed was transported to the feeders in liquid form, in equal portions 10 times per day. Feed accounting in all pens was carried out automatically, on the computer of the feeding system, and additionally, daily, it was recorded in the act of accounting for feed.

The ventilation in all buildings was the same, with the help of the Big Dutchman company's negative pressure system, where the exhaust air was removed with the help of exhaust roof and mine fans, which created negative pressure in the building, and the inflow of fresh air into it was carried out through supply valves. Coordination of the opening of the supply valves with the power of the fans was carried out by a special processor.

Manure removal was vacuum-gravity from the pits under the pens, by opening the plugs in each. Manure was moved to an intermediate storage tank located below the level of the pit bottom. Next, the manure was transported with the help of fecal pumps to the point of its separation into fractions. The solid fraction of manure with a moisture content of 55–65% was stored on the territory of the pig complex, and its liquid fraction was pumped to lagoons outside the pig complex.

The results of the experiment were analyzed in Excel 2010. The results of the measurement of indicators were presented in table of mean values, standard deviations and errors of the mean value. The significance of the discrepancy ($P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$) between the measured microclimate parameters was analyzed using the Kruskal-Wallis test.

Changing the frequency of draining manure pits did not worsen the humane treatment of experimental animals and their usual housing conditions.

## RESULTS AND DISCUSSIONS

Data analysis showed that frequency of emptying manure pits affected the level of their filling (Table 1). Thus, in the control building, where the pits were emptied as manure accumulated in them, its level was probably higher compared to other experimental buildings. In the premises of the II experimental group, where the pits were drained every two weeks, the average level of manure was significantly ($p<0.001$) almost twice (by 21.5 cm or 48.1%) lower compared to the control group I. In the building, where the animals of the III experimental group were kept and the pit was drained every three weeks, such a decrease in the manure level was 16.4 cm, or 36.7% lower ($p<0.01$) than in group I. In the building where animals of the IV experimental group were kept and the pits were drained every four weeks, the level of manure was 28.2% lower than in group I, which was 12.6 cm ($p<0.01$).

Table 1. The level of filling of manure baths and the parameters of the microclimate in the premises at different frequencies of manure discharge, n = 69

| Indicator | | Group I | Group II | Group III | GroupIV |
|---|---|---|---|---|---|
| The average level of manure in the pit, cm | | $44.7 \pm 4.58^{**cd***b}$ | $23.2 \pm 2.96$ | $28.3 \pm 3.34$ | $32.1 \pm 3.93$ |
| Air temperature at the level of the pig's respiratory tract (60 cm), °C | | $19.2 \pm 0.43$ | $19.2 \pm 0.37$ | $18.5 \pm 0.52$ | $19.9 \pm 0.38^{*c}$ |
| Relative humidity, %vol | | $72.5 \pm 0.79$ | $72.1 \pm 0.98$ | $73.3 \pm 0.96$ | $75.1 \pm 0.95^{*ab}$ |
| Gascontent | ammonia($NH_3$). mg/m$^3$ | $15.5 \pm 0.96^{*d}$ | $15.2 \pm 1.70$ | $13.8 \pm 1.04$ | $12.5 \pm 0.85$ |
| | carbondioxide($CO_2$). % vol | $0.2 \pm 0.02$ | $0.2 \pm 0.01$ | $0.2 \pm 0.01$ | $0.2 \pm 0.01$ |
| | hydrogensulfide($H_2S$). mg/m$^3$ | $2.9 \pm 0.23^{***bd**c}$ | $2.1 \pm 0.15$ | $1.9 \pm 0.13$ | $2.2 \pm 0.15$ |

* – $P < 0.05$; ** – $P < 0.01$; *** – $P < 0.001$.
Source: own calculations.

In the building where animals of the II experimental group were kept and the pits were drained after 14 days, the level of manure was 22.0 and 38.4% higher compared to the buildings, where the pigs of the III and IV experimental groups were kept, respectively. At the same time, the level of manure in the pits in the IV experimental building turned out to be 13.4% higher compared to the similar indicator of the III group.

As follows from Table. 1, the air temperature in the premises for fattening pigs corresponded to their physiological needs and was almost independent of the frequency of drainage of manure pits. It turned out to be the lowest in the III experimental group, 18.5°C, which was probably ($p<0.05$) 1.4°C (7.6%) lower compared to the IV experimental group and improbably lower by 0.7°C (3.6%) in comparison with the building, where the animals of the I control and II experimental groups were kept. At the same time, in these buildings, there was a tendency to decrease by 0.7°C or (3.6%) the average value of the temperature in comparison with the building, where the animals of the IV research group were kept.

The relative humidity of the air in all experimental buildings was at the upper limit of physiologically justified norms and also depended on the frequency of pit emptying. As the frequency of pit emptying decreased, the relative humidity of the air in the buildings increased. Thus, in the premises where the animals of the IV experimental group were kept and the pits were drained once every four weeks, the relative humidity of the air was 75.1%, which is 1.8% lower compared to the building where the animals of the III group were kept and the pits were drained every two weeks and lower 3.0% ($p<0.05$) in comparison with the II experimental building, where the pits were drained every week. Also, the humidity level in the building, where the pigs of the control group were kept was lower by 0.8% compared to building with group III and by 2.6 compared to building with group IV, and where pits drained as they filled.

The content of unhealthy gases in the air of the experimental premises also depended to some extent on the frequency of emptying of manure pits. A higher concentration of ammonia was found in the building, where the pits drained as they filled (I control group) – 15.5 mg/m$^3$, which is 0.3 mg/m$^3$ higher compared to the building, where the animals of the II experimental group were kept and by 1.7 and 3.0 ($p<0.05$) mg/m$^3$, respectively, in comparison with building, where animals of III and IV groups were kept. At the same time, the level of ammonia in the indoor air decreased in parallel with the decrease in the frequency of emptying the pits. It should also be noted that the average indicators of the ammonia level for the entire period of the experiment were within the limit of permissible concentrations in all the experimental buildings.

The carbon dioxide content in the air of the buildings did not depend on the frequency of pit emptying and was at the upper limit of the maximum permissible concentrations for fattening pigs.

Meanwhile, the level of hydrogen sulfide had rather low values and depended on the frequency of pit emptying. Its highest content was in the air of the building, where the animals of the control group were kept and the pits were filled and drained according to their maximum filling. In the air of this building, the average concentration of hydrogen sulfide was found at the level of 2.9 mg/m$^3$, which was probably 27.6%, 34.5% ($p<0.001$) and 24.1($p<0.01$) higher compared to the buildings, where animals of II, III, and IV groups were kept, respectively. The level of this indicator in buildings with periodic draining of manure pits had no probable difference, although it had the lowest value in the building, where the pits were drained once every three weeks.

Thus, the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying pits in the premises, while the carbon dioxide content in the air did not depend on it. The average values of air humidity in the building increased with a decrease in the frequency of draining pits. At the same time, the air temperature did not have a clear dependence on the frequency of draining pits.

When studying the dynamics of changes in air parameters in the middle of the building depending on the dynamics of the filling of the pits, a certain regularity of the dependence of the content of its individual components on the level of manure in the pits was established. Thus, the concentration of ammonia in all test buildings increased with an increase in the content of manure in their pits and decreased with their decrease, although this process was not synchronous (Fig. 1).

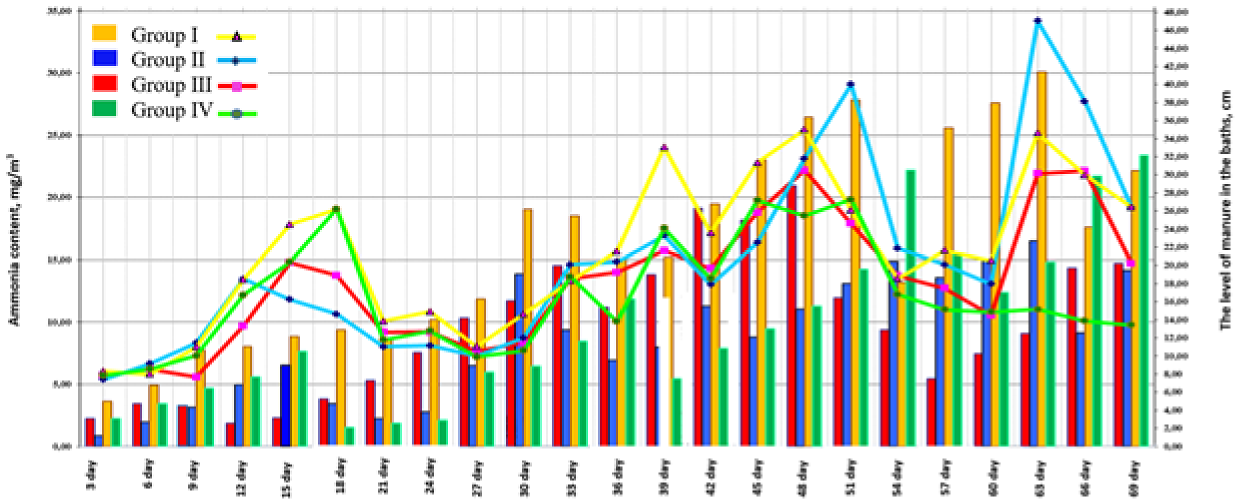


Fig. 1. Dependence of ammonia content on the level of manure in pits
Source: Own calculations.

Thus, an elevated ammonia content was established in all periods of research in the building, where the animals of the I control group were located and the pits traditionally partially drained as they filled. As can be seen from the graph, the highest level of manure in the pits was observed in this building, which in certain periods of research reached the level of 41 cm or 82% of the full capacity of the pit. As can be seen from the same graph, the level of ammonia in the premises of this building was quite high in all periods and almost always exceeded the similar indicator of the experimental groups.

In the II experimental building, where pits were drained according to the methodology every 14 days, after the first draining of the pits, the level of manure in them decreased to 4.7 cm or 9.4% of their full capacity, after which a decrease in the level of ammonia in the air of this building was recorded up to 10.65 mg/m$^3$. In the same period, the ammonia content in the air of the I control group was 19.08 mg/m$^3$ with a level of manure in the pits of 12.9 cm or 25.8%. At the same time, in the building, where pigs of the III experimental group were kept, and the draining of pits took place every 21 days, with 10.6% filling of the pit (5.3 cm), the ammonia content was 13.76 mg/m$^3$, while in the building, where pigs were kept animals of the IV experimental group with a 4.2% level of manure in the pits (2.13 cm), the ammonia level was 9.08 mg/m$^3$.

After the second draining of the pits in the II control group, which took place 29 days after the start of the experiment, as can be seen from this graph, the level of manure in them remained at a fairly high level of 25.8% of their full capacity (12.9 cm), which caused high level of 16.94 mg/m$^3$ ammonia content in the air. At the same time, in the control building, the level of manure in the pits was 51.0% (25.46 cm) and the level of ammonia content was 13.67 mg/m$^3$. After draining the pits 48 days after the start of the experiment, the manure level in them reached 12.12 cm, (25.1% of the maximum filling of the pits), while the ammonia content in the air was 13.02 mg/m$^3$, after which an increase in its level in the premises was observed to fairly high indicators of 29.09 mg/m$^3$ after 51 days and up to 34.22 mg/m$^3$ after 54 days after the start of the experiment, which significantly exceeds the maximum permissible concentrations. At the same time, in the control building, the level of manure in their pits was naturally higher compared to others, while the ammonia content in the air of this building was at a level close to the experimental ones. Thus, the ammonia content in the building changed depending on the level of manure in the pits, but its changes were not synchronous with changes in the level of manure in the pits.

Analyzing the dynamics of the hydrogen sulfide concentration in the test buildings depending on the filling of the pits (Fig. 2), no clear trend was established. However, the graph shows a higher content of hydrogen sulfide in the control building, where the pits were always filled with manure, compared to the experimental buildings, where the pits were periodically emptied.

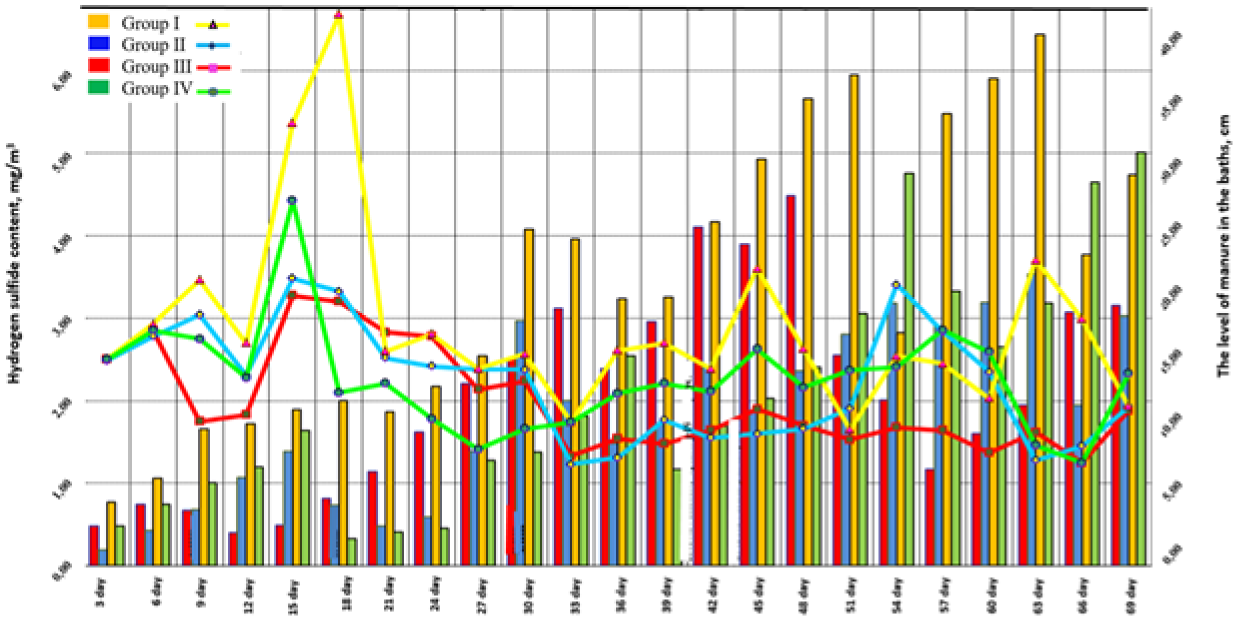


Fig. 2. Dependence of the content of hydrogen sulfide on the level of manure in pits
Source: Own calculations.

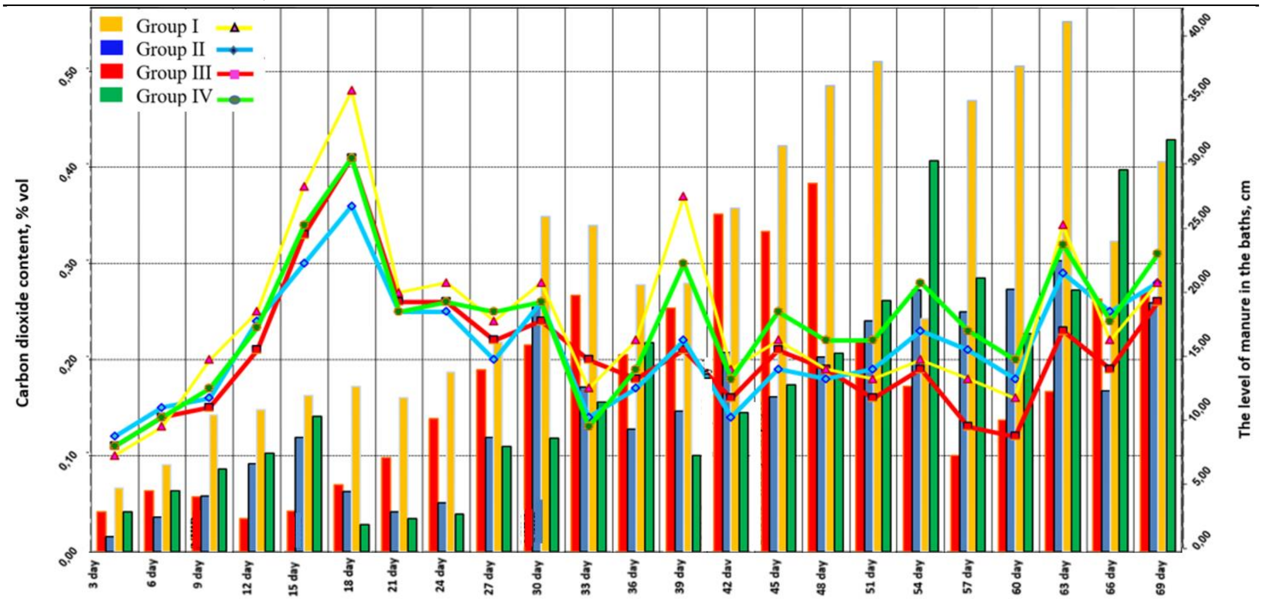


Fig. 3. Dependence of carbon dioxide content on the level of manure in pits
Source: Own calculations.

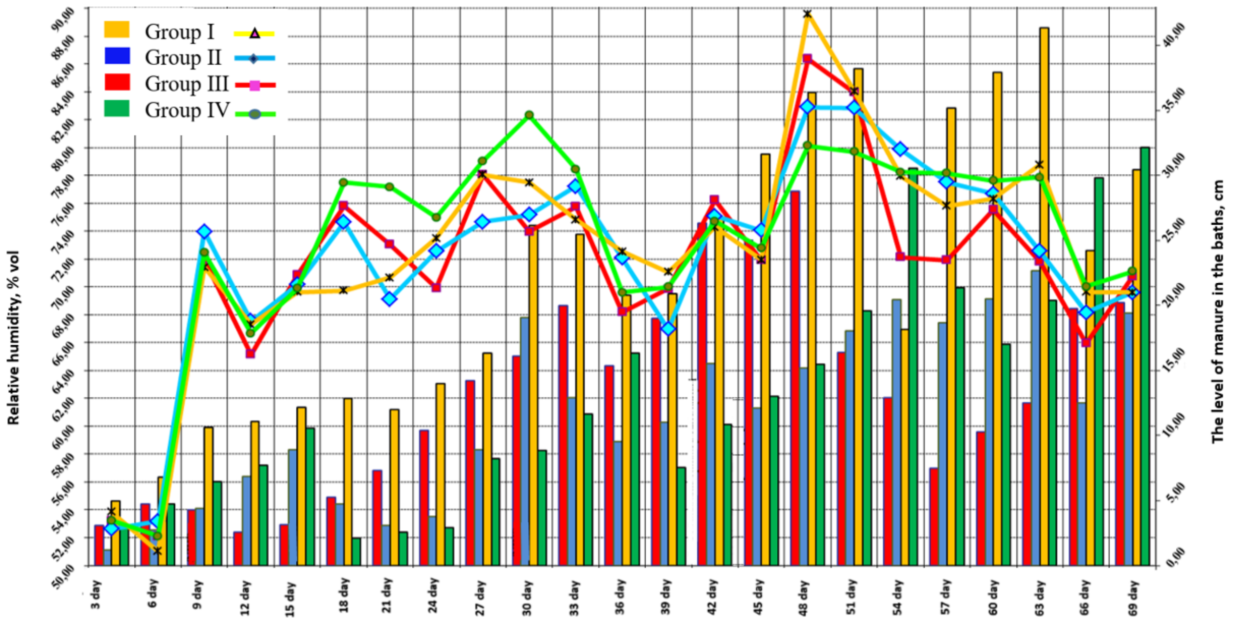


Fig. 4. Dependence of relative air humidity on the level of manure in pits
Source: Own calculations.

The dynamics of the carbon dioxide content in the experimental buildings also did not depend on the level of filling of the pits (Fig. 3), but rather depended on other factors and changed almost synchronously in all four experimental buildings.

At the same time, the values of relative humidity had a significant dependence on the level of fullness of the pits, and with the increase in the level of manure in the pits, the level of relative humidity of the air (Fig. 4) in all experimental buildings also increased.

As can be seen from the graph (Fig. 5), the ammonia content to some extent depended on the temperature outside the building. In our opinion, this is related to the level of intensity of air exchange, which depended on the temperature outside the building. There was not established significant difference between the groups II, III and IV. The concentration of this gas changed almost synchronously in all experimental groups.

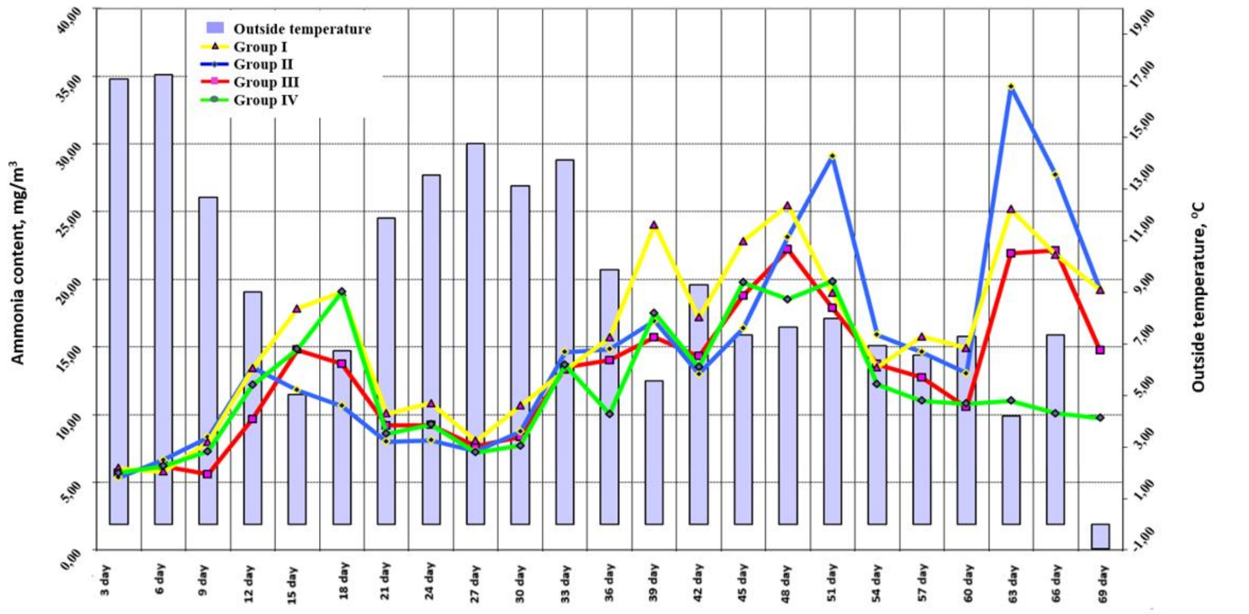


Fig. 5. Dependence of the ammonia content in the air of the experimental premises on the air temperature outside the premises
Source: Own calculations.

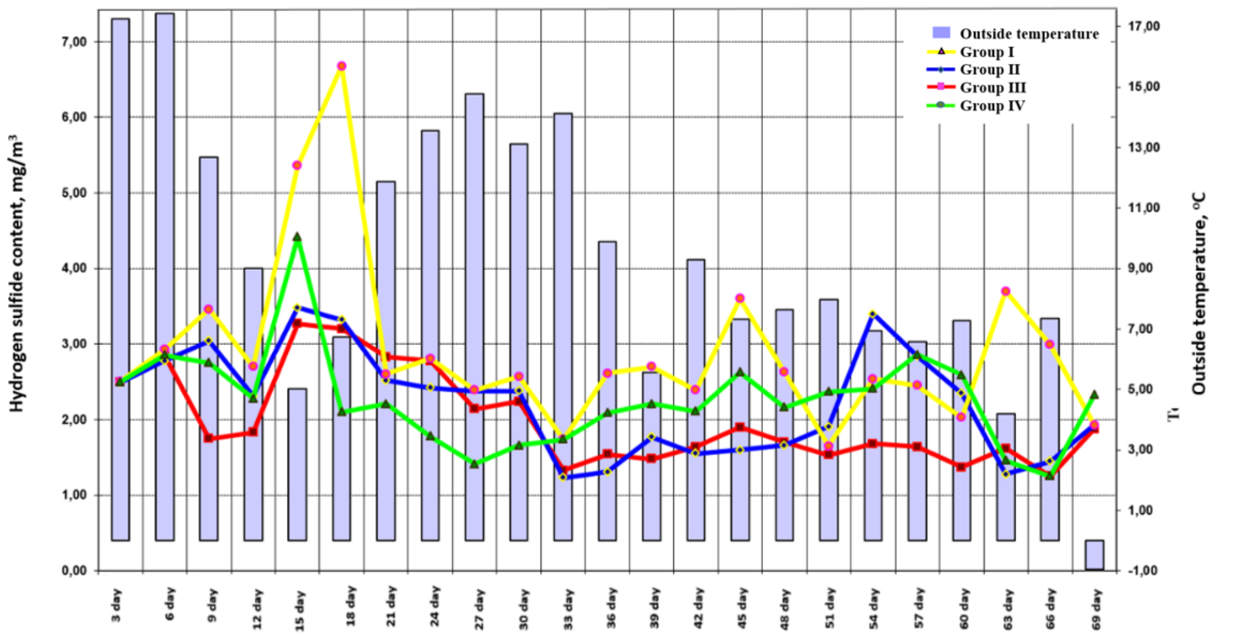


Fig. 6. Dependence of the content of hydrogen sulfide in the air of experimental premises on the temperature of the air outside the premises
Source: Own calculations.

At the same time, the content of hydrogen sulfide, in our opinion, did not depend on the temperature of the external environment (Fig. 6) and had slightly higher values in different buildings, which depended on the frequency of pit emptying.

The dynamics of the carbon dioxide content in the test buildings depended on the temperature outside the building (Fig. 7). As the ambient temperature decreased, the carbon dioxide content in the air increased. In our opinion, this is related to the intensity of air exchange in the building, which is related to the temperature of the outside air.

In the comparison of the experimental groups according to the change of this indicator, there was no any difference between the groups.

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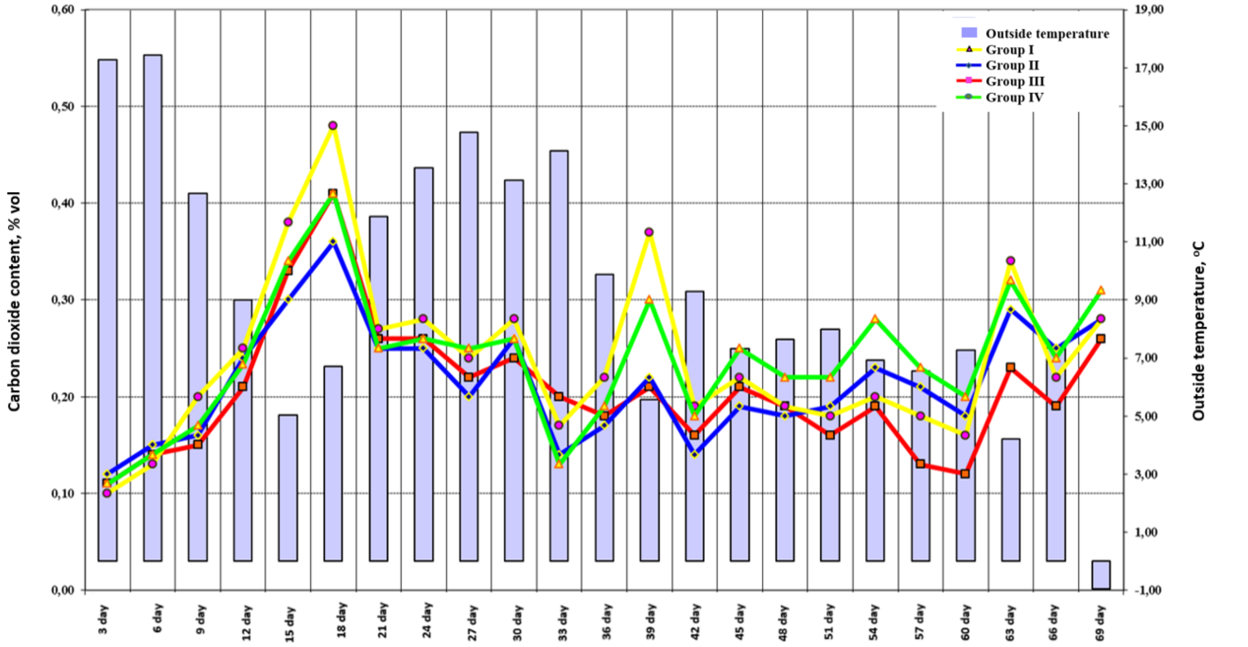


Fig. 7. Dependence of the carbon dioxide content in the air of the experimental premises on the temperature of the air outside the premises
Source: Own calculations.

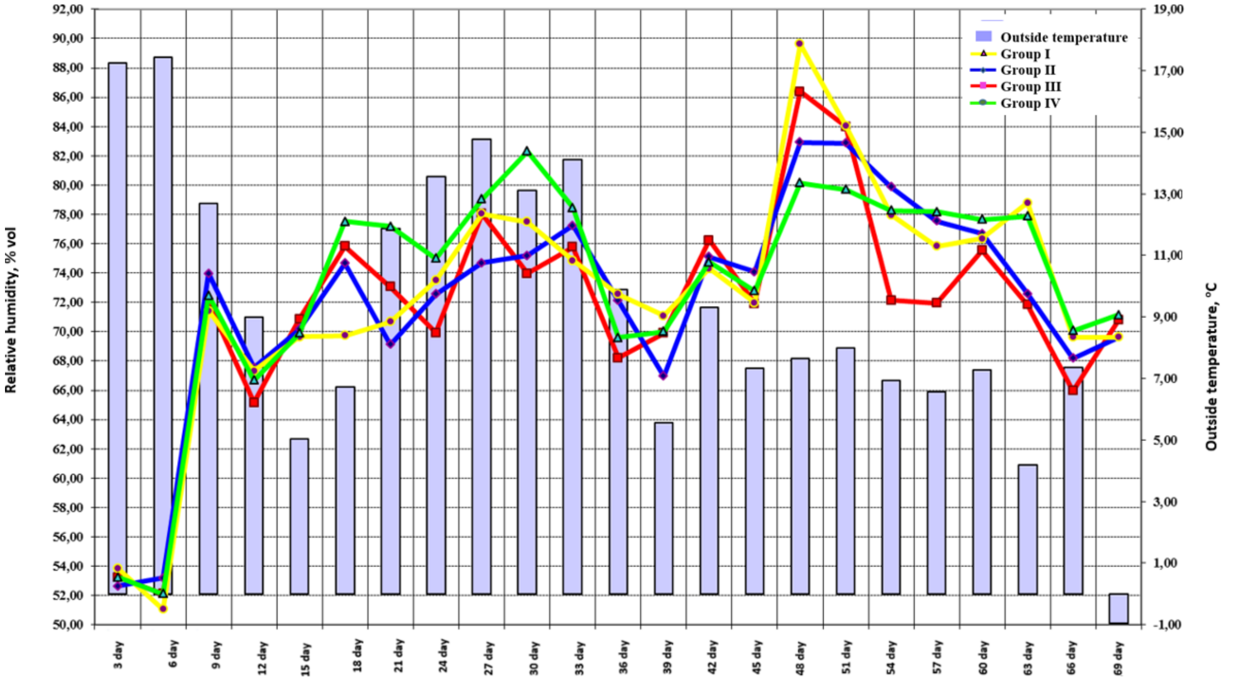


Fig. 8. Dependence of the relative humidity in the air of the experimental premises on the temperature of the air outside the premises
Source: Own calculations.

The relative humidity of the air, as can be seen from the graph (Fig. 8) did not depend on the external temperature as well as on the frequency of pit emptying.

Thus, the content of ammonia and hydrogen sulfide depended on changes in the ambient temperature, while the hydrogen sulfide content in the air and its relative humidity did not depend on the temperature outside the building.

Therefore, our research on the dependence of gas content on the frequency of drainage of manure pits coincided with similar conclusions of other scientists [4, 10, 27].

At the same time, the data we obtained contradicted the arguments presented in the publication [4], which spoke of a decrease in ammonia content with an increase in the frequency of draining manure pits. We obtained the opposite results, which show an increase in the ammonia content with an increase in the frequency of draining the pits. Such conclusions coincided with the results of the experiment [10, 27], which associated the increased concentration of ammonia in the building with their increased evaporation due to the high turbulence of the air flow in the manure-free space of the pit.

We established the lack of influence of the frequency of drainage of manure pits on the concentration of hydrogen sulfide, as did other scientists [9], who had a similar result. However, the absence of such a relationship between the content of hydrogensulfide and the frequency of draining manure pits did not coincide with the data of the authors [29], who confirm an increase in the content of hydrogensulfide in buildings, where pits were cleaned frequently.

## CONCLUSIONS

It was established that the average concentration of hydrogen sulfide and ammonia depended on the frequency of emptying of manure pits in the premises, while the content of carbon dioxide in the air did not depend on it. The average values of air humidity in the building increased with a decrease in the frequency of draining pits.

The dependence of the concentration of ammonia in the air and its relative humidity on the level of manure in the pits and the absence of such dependence in the concentration of hydrogen sulfide and carbon dioxide were determined.

It was proven that the content of ammonia and carbon dioxide depended on changes in the ambient temperature, while the concentration of hydrogen sulfide in the air and its relative humidity did not depend on the temperature outside the building.

Frequent draining of manure pits leads to an increase in the content of ammonia and hydrogen sulfide, which negatively affects the indicators of the microclimate in the pig fattening building.

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# PRODUCTIVITY, ECONOMIC AND ENERGY EFFICIENCY OF SHORT CROP ROTATION UNDER DIFFERENT SYSTEMS OF BASIC TILLAGE AND FERTILIZATION IN THE RIGHT BANK FOREST STEPPE OF UKRAINE

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***Abstract***

*The efficiency of four systems of basic soil tillage and four systems of crop fertilization of five-field crop rotation was studied. Areas of cultivation options were systematically placed in one tier, and fertilizers – in four tiers in a row. Plowing was carried out with a plow, tillage with a deep cultivator, and shallow plowing with a heavy disc harrow. The highest yields of soybeans, winter wheat and corn were under mouldboard, and sunflower and spring barley – under mouldboardless tillage in crop rotation. Under systematic mouldboardless and disk tillage in crop rotation, the yield of all crops decreased significantly, and with increasing fertilizer rates, the difference between these cultivation options and control increased. Crop rotation productivity was almost at the same level under mouldboard and mouldboardless tillage; under the other studied options it was significantly lower. In terms of economic and energy efficiency, under differentiated cultivation the advantage was with the application of 12 tons of manure per hectare of arable land +* $N_{95}P_{82}K_{72}$*. In terms of crop rotation productivity, mouldboard and differentiated tillage were equivalent, and in terms of economic and energy efficiency, the latter exceeded control. For all four variants of tillage in crop rotation, the highest energy efficiency coefficient was recorded for the annual application of 12 tons of manure per hectare of arable land +* $N_{95}P_{82}K_{72}$

***Key words***: *tillage, fertilizers, crop, crop rotation, yield*

## INTRODUCTION

Due to the need to reduce the anthropogenic load on land resources, the intensity of erosion and deflation and other degradation processes, energy intensity of agricultural products, there is a problem of developing and implementing resource- and moisture-saving soil protection systems of mechanical tillage under conditions of gradual climate deterioration.

The question of expediency and efficiency of different systems of mechanical tillage in agriculture of Ukraine remains the most debatable, ambiguous and controversial during the XIX-XXI centuries [13, 14].

At the end of the last century, some domestic scientists advocated the complete abandonment of the use of plows by replacing them with disc, flat, chisel and other mouldboardless tools [3, 21, 5, 22, 8, 2, 23].

However, as it turned out, constant mouldboardless tillage leads, first of all, to the deterioration of phytosanitary conditions of agrophytocenoses (despite the widespread use of pesticides), as well as to the differentiation of the arable soil layer (to which different crops respond differently) by indicators and conditions of fertility, local acidification of soils, reducing the depth of the root layer and the duration of the aftereffect of manure, compaction of the lower parts of the arable layer [15, 6, 7, 12, 11, 19].

Today, most domestic researchers prefer a differentiated (combined) system of basic tillage, which provides a scientific combination of different methods, measures and means of its implementation at different depths depending on agrophysical, agrochemical and biological indicators of soil fertility, biological features of cultivated crops, climatic, weather and landscape conditions, resource and energy potential of farms to ensure the production of environmentally safe and economically reasonable competitive agricultural products with optimal agri-environmental efficiency [9, 16, 24, 20, 17, 18, 26].

On ordinary medium loam black soil of the Right Bank Steppe of Ukraine the highest agrotechnological effect in crop rotation was provided by a combination of plowing for row crops with "zero" cultivation for agricultural plants of conventional row sowing method, in which the level of profitability and energy efficiency factor on 74.6 and 44.0% higher, compared with different depth plowing [4].

On ordinary heavy loamy black soil of the Northern Steppe of Ukraine, mouldboard, differentiated and shallow (mulching) tillage systems in the five-field crop rotation were equivalent in terms of productivity, except for unfertilized options, where the latter was inferior to the first two by 5.5-7.5%. The highest economic efficiency under the mulching system – the level of profitability was 84-115%. During the mouldboard tillage, this figure decreased to 75-105%. In short crop rotations, the scientist recommends a differentiated system of cultivation on flat lands and mulching – on deflation-hazardous soils. The researcher proposes plowing for corn with reversible plows to a depth of 23-25 cm with differentiated tillage in crop rotation and flat-cutting tillage with tools CR-4,5 or CWRST-5,6 “Resident” at 14-16 cm for shallow tillage [28].

On the typical low-humus medium-loamy black soil in the typical grain ten-field crop rotation of the Forest-Steppe of Ukraine, among the studied main tillage systems, the most energy efficient was differentiated and mouldboard-mouldboardless. The latter one, which is recommended for production, involves plowing with a tiered plow in two fields of crop rotation for sugar beets, and for the rest of the crops – cultivation with flat and disk tools at different depths [27].

In Northern Steppe of Ukraine, the Institute of Agriculture of the steppe zone of NAAS offers plowing for corn and sunflower to a depth of 25-27 cm, and on erosion-hazardous lands – flat cultivation on ordinary low-humus black soil [25].

Kharkiv NAU recommends to the farms of the Left Bank Forest-Steppe and Northern Steppe: deep (not less than 25-27 cm) plowing once in three or four years for row crops, first of all sugar beet; to increase the share of chisel (mouldboardless) deep and medium tillage for the cultivation of legumes, spring cereals and sunflower to 30-50%; surface and shallow tillage with disc and combined implements for winter cereals, as well as partially for spring ear crops, especially when growing them after the late predecessors; direct sowing should be applied periodically and first of all under grain ear crops for harvesting them after late predecessors, with low weediness of fields and chemical weeding if necessary [20].

On typical deep black soil in the Right Bank Forest-Steppe of Ukraine the highest agrotechnical, economic and energy efficiency in fodder five-field crop rotation was reached at long shallow cultivation providing deep (on 30-32 cm) cultural plowing under fodder beets (where manure is applied), and under the rest of agrophytocenoses – peeling by 10-12 cm with heavy disc harrow and mouldboard cultivator [12].

A number of scientists propose a two-phase basic tillage, in which the first phase includes the preparation of the seedbed to the minimum depth and sowing of agricultural crops, the second – actually the main (mouldboardless) tillage to the full depth of the arable layer after sowing in the presence of weed seedlings or after their appearance in the early stages of organogenesis of the cultural component of agrophytocenoses [10].

On typical deep medium loamy black soil in LLC “Agro-firm Kolo” Skvyra district of Kyiv region, the highest profitability (74.3%) of grain ten-field crop rotation during 2011-2018 was obtained by mouldboard-mouldboardless tillage, which provided for plowing in two fields (under sugar beets and sunflowers), and in the rest of the fields – different depths of mouldboardless hoeing. Under systematic disk tillage for all crop rotations to a depth of 8-10 cm, this indicator was lower on 14.2% [26].

Today the role of plowing in modern farming is being reconsidered, especially from the standpoint of agrophysical condition of soils. In particular, a fairly respectable generality of domestic agricultural scientists proves that plowing should be carried out with plows with plowshares or two-tiered plows only when the coefficient of structure of the upper soil layer (8-10 cm) is less than 0.76. Under plowing without plowshares, the arable layer is homogeneous, with plowshares – heterogeneous (lower – sprayed, upper – structured). Scientists point to a fundamentally important postulate of aerobic conditions in the upper and anaerobic in the lower parts of the arable layer, based on sufficient experimental material of Williams [29] and other well-known soil scientists. The task of swapping two layers of soil without any mixing (which is in principle unacceptable) can now be solved only by a plow, but it must be equipped with plowshares [1].

The purpose of the study was to establish the most effective combination of basic tillage and fertilizer systems, which provides 4.6 tons of dry matter, 6.4 tons of fodder units and 0.54 tons of digestible protein of marketable crop products at the highest economic and energy efficiency.

## MATERIALS AND METHODS

The experimental work was performed on a typical deep low-humus medium-loam black soil in experimental field of Bila Tserkva National Agrarian University during 2018-2021 in a stationary field grain five-field crop rotation. Four systems of basic tillage (Table 1) and four systems of fertilizer (Table 2) in crop rotation were studied.

In the experiment threefold repetition was used. Repetitions on the area were placed systematically, continuously.

Plots with different tillage options (first order) were placed sequentially, systematically in one tier, and with fertilizer levels (second order) – sequentially in four tiers. The sown and registered area of the first order plots was 684 $m^2$ (9 × 76) and 448 $m^2$ (7 × 64), respectively, the second – 171 $m^2$ (9 × 19) and 112 $m^2$ (7 × 16). The area of each field without the surrounding protective strips was 7835.6 $m^2$ (73 × 103.1). The total number of elementary plots was 240, and the area under the experiment was 3.7 hectares.

Plowing was performed with a plow PPM-3-35, chisel (mouldboardless) tillage – with a deep cultivator DR-3.4, and disk (mouldboard) – with a heavy disc harrow HDH-3.0.

From fertilizers, semi-rotted manure (on straw litter) of cattle, ammonium nitrate, potassium salt, and simple granular superphosphate were applied. The crop was harvested by direct combining.

Table 1. Systems of basic tillage in crop rotation

| Field No | Crop in crop rotation | Tillage* | | | |
|---|---|---|---|---|---|
| | | mouldboard (control) | mouldboardless | mouldboard & mouldboardless (differentiated) | disking (continuous shallow) |
| | | Depth (cm) and cultivation | | | |
| 1 | Soybean | 16-18 (p.) | 16-18 (d.t.) | 16-18 (r) | 10-12 (d.h.) |
| 2 | Winter wheat + white mustard on green manure | 10-12 (d.h.) | 10-12 (d.t.) | 10-12 ( d.h.) | 10-12 (d.h.) |
| 3 | Sunflower | 25-27 (p.) | 25-27 (d.t.) | 25-27 (p.) | 10-12 (d.h.) |
| 4 | Spring barley + white mustard on green manure | 10-12 (d.h.) | 10-12 (d.t.) | 10-12 (d.h.) | 10-12 (d.h.) |

Source: Authors' own results.
*Note: p. – plowing, d.h. – disc harrow, d.t. – deep tiller.

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Table 2. Fertilizer systems under crops of field grain-plowing crop rotation

| N of field | Crop rotation crops | Fertilizer level | Manure, t/ha | Mineral fertilizers, kg/ha a.s. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Total | | | Basic fertilizer | | | Under pre-sowing cultivation | | | Row fertilizer | | | Feeding N |
| | | | | N | P | K | N | P | K | N | P | K | N | P | K | |
| 1 | Soybean | 0 | | | | | | | | | | | | | | |
| | | 1 | | 30 | 40 | 30 | | 40 | 30 | 30 | | | | | | |
| | | 2 | | 40 | 60 | 40 | | 60 | 40 | 40 | | | | | | |
| | | 3 | | 60 | 80 | 60 | | 80 | 60 | 60 | | | | | | |
| 2 | Winter wheat | 0 | | | | | | | | | | | | | | |
| | | 1 | | 100 | 70 | 50 | 30 | 70 | 50 | | | | | | | 70 |
| | | 2 | | 125 | 90 | 70 | 30 | 90 | 70 | | | | | | | 95 |
| | | 3 | | 150 | 110 | 80 | 30 | 110 | 80 | | | | | | | 120 |
| | White mustard on green manure | 0 | | | | | | | | | | | | | | |
| | | 1 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| | | 2 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| | | 3 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| 3 | Sunflo-wer | 0 | | | | | | | | | | | | | | |
| | | 1 | 20 | 50 | 50 | 35 | 50 | 50 | 35 | | | | | | | |
| | | 2 | 30 | 80 | 80 | 50 | 80 | 80 | 50 | | | | | | | |
| | | 3 | 40 | 100 | 100 | 70 | 100 | 100 | 70 | | | | | | | |
| 4 | Spring barley | 0 | | | | | | | | | | | | | | |
| | | 1 | | 50 | 40 | 40 | | 40 | 40 | 50 | | | | | | |
| | | 2 | | 60 | 50 | 50 | | 50 | 50 | 60 | | | | | | |
| | | 3 | | 70 | 60 | 60 | | 60 | 60 | 70 | | | | | | |
| | White mustard on green manure | 0 | | | | | | | | | | | | | | |
| | | 1 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| | | 2 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| | | 3 | | 15 | 15 | 15 | 15 | 15 | 15 | | | | | | | |
| 5 | Maize | 0 | | | | | | | | | | | | | | |
| | | 1 | 20 | 120 | 90 | 100 | | 80 | 100 | 120 | | | | 10 | | |
| | | 2 | 30 | 140 | 100 | 120 | | 90 | 120 | 140 | | | | 10 | | |
| | | 3 | 40 | 150 | 120 | 130 | | 110 | 130 | 150 | | | | 10 | | |
| Per 1 ha of crop rotation | | 0 | | | | | | | | | | | | | | |
| | | 1 | 8 | 76 | 64 | 57 | 22 | 62 | 57 | 40 | | | | 2 | | 14 |
| | | 2 | 12 | 95 | 82 | 72 | 28 | 80 | 72 | 48 | | | | 2 | | 19 |
| | | 3 | 16 | 112 | 100 | 86 | 32 | 98 | 86 | 56 | | | | 2 | | 24 |

Source: Authors' own results.

## RESULTS AND DISCUSSIONS

Soybean yield was the highest (on average 2.50 t/ha) under mouldboard tillage in crop rotation; under mouldboardless, differentiated and disk, it was respectively, 0.47, 0.13 and 0.39 t/ha or on 18.8, 5.2 and 15.4% lower (Table 3).

As the level of applied fertilizers increased, the difference in yield between cultivation options increased as well. Thus, in the unfertilized areas, fertilized with $N_{30}P_{40}K_{30}$, $N_{40}P_{60}K_{40}$ and $N_{60}P_{80}K_{60}$ grain was obtained less, respectively, on 0.31, 0.43, 0.53 and 0.62 t/ha under chisel, 0.08, 0.12, 0.15 and 0.18 – mouldboard-mouldboardless, 0.26, 0.35, 0.42 and 0.54 t/ha under shallow cultivation than in the control. Yields of winter wheat under mouldboardless and disc tillage in crop rotation were significantly lower (on average on 0.59 and 0.49 t/ha, respectively), and under differentiated – insignificantly (0.20 t/ha) less than in the control, and as fertilizer rates increased, these differences became more pronounced. On unfertilized variants, with the application of $N_{100}P_{70}K_{50}$, $N_{125}P_{90}K_{70}$ and $N_{150}P_{110}K_{80}$, grain yield was lower on 0.43, 0.56, 0.63 and 0.1 t/ha under chisel cultivation, 0.12, 0.18, 0.23 and 0.27 – mouldboard-mouldboardless, 0.33, 0.46

Table 3. Crop yields under different tillage and fertilizer systems, t/ha

| The main tillage in crop rotation | Fertilizer levels in crop rotation | Soybean | Winter wheat | Sunflower | Spring barley | Corn | White mustard for green manure | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | after winter wheat | after spring barley |
| Mouldboard (control) | 0 | 1.12 | 2.73 | 1.21 | 2.37 | 4.82 | 9.86 | 8.83 |
| | 1 | 2.11 | 4.78 | 2.09 | 3.74 | 7.90 | 17.75 | 14.10 |
| | 2 | 2.96 | 6.35 | 2.98 | 4.78 | 9.73 | 21.88 | 18.26 |
| | 3 | 3.81 | 7.80 | 3.69 | 5.67 | 11.74 | 23.79 | 21.09 |
| Mouldboardless (chisel) | 0 | 0.81 | 2.30 | 0.96 | 2.05 | 4.28 | 8.63 | 7.50 |
| | 1 | 1.68 | 4.22 | 1.81 | 3.32 | 7.19 | 16.30 | 12.51 |
| | 2 | 2.43 | 5.72 | 2.62 | 4.29 | 8.85 | 20.21 | 16.47 |
| | 3 | 3.19 | 7.09 | 3.24 | 5.11 | 10.78 | 21.95 | 19.13 |
| Differentiated | 0 | 1.04 | 2.61 | 1.45 | 2.53 | 4.58 | 9.48 | 10.28 |
| | 1 | 1.99 | 4.60 | 2.42 | 3.87 | 7.59 | 17.26 | 15.44 |
| | 2 | 2.81 | 6.12 | 3.38 | 4.86 | 9.35 | 21.23 | 19.53 |
| | 3 | 3.63 | 7.53 | 4.14 | 5.73 | 11.32 | 22.98 | 22.28 |
| Shallow (disk) | 0 | 0.86 | 2.40 | 0.86 | 2.13 | 4.17 | 8.31 | 7.19 |
| | 1 | 1.76 | 4.32 | 1.66 | 3.41 | 7.05 | 15.96 | 12.22 |
| | 2 | 2.54 | 5.79 | 2.47 | 4.40 | 8.76 | 19.91 | 16.19 |
| | 3 | 3.27 | 7.19 | 3.11 | 5.25 | 10.64 | 21.66 | 18.89 |
| $SD_{0.05}$ | | 0.24 | 0.33 | 0.21 | 0.22 | 0.46 | 0.98 | 0.870.87 |

Source: Authors' own results.

The yield of sunflower seeds was significantly higher under differentiated (on average 0.36 t/ha) and significantly lower under mouldboardless (0.33 t/ha) and especially disk (0.46 t/ha) than under mouldboard tillage in crop rotation, where the average value of this indicator was 2.49 t/ha. On unfertilized plots, fertilized with 20 t/ha of manure + $N_{50}P_{50}K_{35}$, 30 t/ha of manure + $N_{80}P_{80}K_{50}$ and 40 t/ha of manure + $N_{100}P_{100}K_{70}$, oilseeds were collected, respectively, on 0.25, 0.28, 0.36 and 0.45 t/ha less than under chisel, on 0.35, 0.43, 0.51 and 0.58 – under disk cultivation and on 0.24, 0.33, 0.40 and 0.45 t/ha more under differentiated cultivation than in control. Thus, deep cultivation in crop rotation once during the rotation period and under this crop provided its highest yield, the average of which according to the experimental options reached 2.85 t/ha.

Yields of spring barley under chisel and shallow cultivation were on 0.45 and 0.34 t/ha (10.9 and 8.2%) lower, respectively, and under mouldboard-mouldboardless – on 0.11 t/ha (2.7%) higher than in the control. On unfertilized versions, fertilized with $N_{50}P_{40}K_{40}$, $N_{60}P_{50}K_{50}$ and $N_{70}P_{60}K_{60}$, this figure was, respectively, on 0.32, 0.42, 0.49 and 0.56 t/ha under mouldboardless and on 0.24, 0.33, 0.38 and 0.42 t/ha under disk tillage lower, and under differentiated – on 0.16, 0.13, 0.08 and 0.06 t/ha higher than in the control.

Yield of corn under chisel, mouldboard-mouldboardless and constant shallow tillage in crop rotation, compared with mouldboard, was, respectively, less on 0.77, 0.34 and 0.89 t/ha (9.0, 4.0 and 10.4%). Fertilizers increased the difference between cultivation options, which at the highest rate exceeded unfertilized areas in 1.7-1.8 times. Thus, on unfertilized variants, fertilized with 20 t/ha of manure + $N_{120}P_{90}K_{100}$, 30 t/ha of manure + $N_{140}P_{100}K_{120}$ and 40 t/ha of manure + $N_{150}P_{120}K_{130}$ corn grain was obtained less, respectively, on 0.54, 0.71, 0.88 and 0.96 t/ha under mouldboardless, 0.24, 0.31, 0.38 and 0.42 – differentiated and 0.65, 0.85, 0.97 and 1.10 t/ha under disk tillage, than in the control.

Regarding the collection of fodder units of marketable products from each hectare of agrophytocenoses, crop rotations were in the following descending order: corn – 10.79 t/ha, winter wheat – 5.97; spring barley – 4.88; soybeans – 2.75; sunflower – 1.86.

As for the yield of digestible protein, the sequence of crops was as follows: soybeans – 0.615 t/ha; corn – 0.507; winter wheat – 0.434; sunflower – 0.343; spring barley – 0.282 t/ha.

Under both predecessors in the crop rotation, green mass of white mustard came to the soil significantly less than under chisel and disk tillage than in the control. Productivity of siderate crop under differentiated cultivation, in comparison with mouldboard tillage, was insignificantly lower (on 0.38-0.81 t/ha) in the link with winter wheat and significantly higher (on 1.19-1.45 t/ha) under its sowing after spring barley.

With the main production of agrophytocenoses of crop rotation from each hectare of arable land, it was received 4.00 tons of dry matter, 5.58 tons of feed units and 0.467 tons of digestible protein under mouldboard tillage, 3.55, 4.96 and 0.406, respectively – under chisel, 3.96, 5.49 and 0.464 – mouldboard-mouldboardless and 3.55 tons of dry matter, 4.97 tons of feed units and 0.407 tons of digestible protein under systematic shallow tillage (Table 4).

Taking into account the by-products of winter wheat and spring barley, the above indicators of crop rotation productivity were, respectively, 5.94, 6.29 and 0.483 tons under mouldboard tillage, 5.37, 5.62 and 0.421 – mouldboardless, 5.91, 6.21 and 0.481 – differentiated and 5.39, 5.65 and 0.423 tons under disk tillage.

The highest ratio of grain to straw was recorded under mouldboard tillage in crop rotation, which for winter wheat was 1,228, spring barley – 1,096, that is on 4.5 and 6.8% more than under chisel, 1.5 and 1.8% – mouldboard-mouldboardless, 2.9 and 5.8% – shallow tillage.

Table 4. Collection of dry matter of crops and crop rotation productivity under different systems of tillage and fertilizers, t/ha

| The main tillage in crop rotation | Fertilizer levels in crop rotation | Soybean (grain) | Winter wheat (grain + straw) | Sunflower (seeds) | Spring barley (grain + straw) | Corn (grain) | Crop rotation productivity | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | taking into account the by-products of cereals | taking into account only the basic products of all crops |
| Mouldboard (control) | 0 | 0.98 | 5.15 | 1.02 | 4.25 | 4.20 | 3.12 | 2.12 |
| | 1 | 1.85 | 9.07 | 1.76 | 6.78 | 6.89 | 5.27 | 3.57 |
| | 2 | 2.60 | 12.18 | 2.52 | 8.75 | 8.48 | 6.91 | 4.64 |
| | 3 | 3.34 | 15.10 | 3.11 | 10.50 | 10.24 | 8.46 | 5.66 |
| Mouldboardless (chisel) | 0 | 0.71 | 4.45 | 0.81 | 3.81 | 3.73 | 2.70 | 1.80 |
| | 1 | 1.47 | 8.23 | 1.53 | 6.26 | 6.27 | 4.75 | 3.15 |
| | 2 | 2.13 | 11.22 | 2.21 | 8.13 | 7.72 | 6.28 | 4.14 |
| | 3 | 2.80 | 14.03 | 2.73 | 9.75 | 9.40 | 7.74 | 5.09 |
| Differentiated | 0 | 0.91 | 4.95 | 1.22 | 4.59 | 3.99 | 3.13 | 2.11 |
| | 1 | 1.75 | 8.83 | 2.04 | 7.09 | 6.62 | 5.27 | 3.54 |
| | 2 | 2.46 | 11.86 | 2.85 | 8.98 | 8.15 | 6.86 | 4.58 |
| | 3 | 3.18 | 14.70 | 3.49 | 10.70 | 9.87 | 8.39 | 5.59 |
| Shallow (disk) | 0 | 0.75 | 4.59 | 0.73 | 3.93 | 3.64 | 2.73 | 1.80 |
| | 1 | 1.54 | 8.33 | 1.40 | 6.38 | 6.15 | 4.76 | 3.15 |
| | 2 | 2.23 | 11.28 | 2.08 | 8.28 | 7.64 | 6.30 | 4.14 |
| | 3 | 2.87 | 14.14 | 2.62 | 9.96 | 9.28 | 7.77 | 5.10 |

Source: Authors' own results.

On unfertilized areas, fertilized with 8 tons of manure + $N_{76}P_{64}K_{57}$, 12 tons of manure + $N_{95}P_{82}K_{72}$ and 16 tons of manure + $N_{112}P_{100}K_{86}$ per hectare of arable land, crop rotation productivity was 2.12, 3.57, 4.64 and 5.66 tons of dry matter of marketable products under mouldboard tillage in crop rotation; 1.80, 3.15, 4.14 and 5.09 tons – mouldboardless; 2.11, 3.54, 4.58 and 5.59 tons – differentiated; 1.80, 3.15, 4.14 and 5.10 tons under disk tillage in crop rotation ($SD_{0.05}$ = 0.24 tons). Taking into account the by-products of cereals (straw of winter wheat and spring barley), the collection of feed units for fertilizer options was, respectively, 3.35, 5.62, 7.29 and 8.90 tons under mouldboard tillage; 2.87, 5.01, 6.55 and 8.06 – chisel; 3.32, 5.56, 7.18 and 8.76 – mouldboard-mouldboardless; 2.89, 5.02, 6.58 and 8.09 tons under shallow tillage in crop rotation ($SD_{0.05}$ = 0.39 tons), and the yield of digestible protein was, respectively, 0.245, 0.424, 0.565 and 0.699 tons under mouldboard tillage; 0.202, 0.367, 0.496 and 0.619 – mouldboardless, 0.246, 0.422, 0.561 and 0.693 – differentiated; 0.204, 0.368, 0.499 and 0.621 tons under disk tillage ($SD_{0.05}$ = 0.21 tons).

The best indicators of economic efficiency were obtained under mouldboard-mouldboardless tillage in crop rotation, in which the cost of growing crops and the cost of one ton of feed units, respectively, were on 2.2 and 1.2% lower, and the cost of gross output, net profit and profitability, respectively, on 2.2, 9.1 and 6.9% higher than in the control. Under constant shallow tillage, economic efficiency indicators turned out to be the worst: total costs for growing crops, the value of gross output, profit and profitability, respectively, on 5.2, 11.4, 23.5 and 9.6% lower, and the cost was 6.3% higher than mouldboard tillage in crop rotation.

The first four indicators listed above were, respectively, on 9.5, 11.9, 17.1 and 3.8% higher, and the cost was on 1.0% lower under mouldboard than disk tillage in crop rotation (Table 5).

Table 5. Economic efficiency of different systems of basic tillage and fertilization in crop rotation

| The main tillage in crop rotation | Fertilizer levels in crop rotation | Total costs, thousand UAH/ha | Cost of gross output, thousand UAH/ha | Cost of 1 t of fodder units, thousand UAH | Conditionally net profit, thousand UAH/ha | Profitability, % |
|---|---|---|---|---|---|---|
| Mouldboard (control) | 0 | 11.42 | 15.08 | 3.85 | 3.66 | 32.0 |
| | 1 | 16.85 | 25.48 | 3.37 | 8.63 | 51.2 |
| | 2 | 26.39 | 42.88 | 4.09 | 16.49 | 62.5 |
| | 3 | 40.41 | 62.44 | 5.13 | 22.03 | 54.5 |
| Mouldboardless (chisel) | 0 | 10.34 | 12.80 | 4.07 | 2.46 | 23.8 |
| | 1 | 15.70 | 22.32 | 3.55 | 6.62 | 42.2 |
| | 2 | 25.03 | 38.11 | 4.34 | 13.08 | 52.2 |
| | 3 | 39.02 | 56.05 | 5.50 | 17.03 | 43.6 |
| Differentiated | 0 | 10.84 | 15.13 | 3.69 | 4.29 | 39.5 |
| | 1 | 16.33 | 25.93 | 3.32 | 9.60 | 58.8 |
| | 2 | 25.91 | 44.05 | 4.08 | 18.14 | 70.0 |
| | 3 | 39.89 | 63.72 | 5.15 | 23.83 | 59.7 |
| Shallow (disk) | 0 | 9.75 | 12.74 | 3.82 | 2.99 | 30.7 |
| | 1 | 14.85 | 21.96 | 3.35 | 7.11 | 47.9 |
| | 2 | 24.31 | 37.88 | 4.20 | 13.57 | 55.8 |
| | 3 | 37.09 | 55.88 | 5.22 | 18.79 | 50.7 |

Source: Authors' own results.

The lowest cost of one ton of fodder units in all cultivation options was recorded under the application of 8 tons of manure per hectare of arable land + $N_{76}P_{64}K_{57}$, and the highest profitability – under fertilizing with 12 tons of manure + $N_{95}P_{82}K_{72}$. These figures were respectively 3.37 thousand UAH and 62.5% under mouldboard tillage, 3.55 and 52.2 – chisel, 3.32 and 70.0 – mouldboard-mouldboardless, 3.35 thousand UAH and 55.8% under shallow tillage in crop rotation.

The highest energy costs for growing crop products were recorded under shelf tillage in crop rotation – 42.8 GJ/ha, under mouldboardless, differentiated and disk, they were, respectively, on 3.3, 4.2 and 7.7% lower (Table 6).

It should be noted that chisel hoeing is a less energy-intensive measure than plowing, but further additional operations with heavy tillage implements in the crop rotation cycle offset this advantage. And the direct operating costs on mechanical tillage under the inclusion of energy equivalents of pesticides (6-8%) and fertilizers (up to 60%) use are currently up to 5-8% [14].

Table 6. Energy efficiency of different systems of basic tillage and fertilization in crop rotation

| The main tillage in crop rotation | Fertilizer levels in crop rotation | Total energy consumed, GJ/ha | Energy output with yield, GJ/ha | | Energy efficiency ratio | |
|---|---|---|---|---|---|---|
| | | | main products | all products | main products | all products |
| Mouldboard (control) | 0 | 23.9 | 37.0 | 75.2 | 1.5 | 3.1 |
| | 1 | 32.4 | 62.3 | 140.8 | 1.9 | 4.3 |
| | 2 | 46.8 | 137.5 | 273.5 | 2.9 | 5.8 |
| | 3 | 68.1 | 173.0 | 330.0 | 2.5 | 4.8 |
| Mouldboardless (chisel) | 0 | 22.8 | 30.5 | 63.8 | 1.3 | 2.8 |
| | 1 | 31.2 | 55.0 | 124.2 | 1.8 | 4.0 |
| | 2 | 45.5 | 122.8 | 244.0 | 2.7 | 5.4 |
| | 3 | 66.3 | 155.1 | 296.7 | 2.3 | 4.5 |
| Differentiated | 0 | 22.3 | 37.5 | 77.2 | 1.7 | 3.5 |
| | 1 | 30.5 | 63.0 | 142.3 | 2.1 | 4.7 |
| | 2 | 44.8 | 137.4 | 276.0 | 3.1 | 6.2 |
| | 3 | 66.3 | 175.7 | 335.2 | 2.7 | 5.1 |
| Shallow (disk) | 0 | 21.2 | 30.2 | 63.3 | 1.4 | 3.0 |
| | 1 | 29.6 | 55.2 | 124.9 | 1.9 | 4.2 |
| | 2 | 43.5 | 121.2 | 243.4 | 2.8 | 5.6 |
| | 3 | 63.7 | 155.0 | 296.0 | 2.4 | 4.6 |

Source: Authors' own results.

The coefficients of energy efficiency of marketable and all crop products under chisel tillage in crop rotation were 9.1 and 6.7%, respectively, under shallow – on 4.5 and 4.4% lower, and under mouldboard-mouldboardless on 9.1 and 8.9 % higher than in the control. In all studied variants of tillage, the energy efficiency coefficient reached the highest values with the application of 12 tons of manure per hectare of arable land + $N_{95}P_{82}K_{72}$. On average, according to the experiment, the coefficient of energy efficiency of the main and all agricultural products was, respectively, 2.2 and 4.5 under mouldboard tillage in crop rotation, 2.0 and 4.2 – mouldboardless, 2.4 and 4.9 – mouldboard-mouldboardless, 2.1 and 4.4 under disk tillage.

Thus, in terms of crop rotation productivity, mouldboard and differentiated cultivation were almost equivalent, and in terms of economic and energy efficiency, the advantage in most cases was under mouldboard-mouldboardless tillage, which involves deep cultivation in only one field, and in other fields – tillage with a disc harrow and a cultivator.

Under chisel and shallow tillage these indicators worsen.

## CONCLUSIONS

Yields of soybeans, winter wheat and white mustard and corn were higher under mouldboard, but sunflower, spring barley and white mustard – higher under differentiated tillage in crop rotation.

All crops significantly reduced this figure under chisel and constant shallow tillage.

Crop rotation productivity was almost at the same level under mouldboard and mouldboard-mouldboardless tillage, under chisel and disk it was significantly lower.

The highest indicators of economic and energy efficiency were provided by the main differentiated tillage of typical black soil in grain five-field crop rotation, in which deep cultivation of 25-27 cm was carried out in one field (for row-crop, where manure was applied), and in the rest of the fields – disking and chiselling.

The most economically and energy-efficient norm was the application of 12 tons of manure per hectare of arable land + $N_{95}P_{82}K_{72}$.

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# STUDY ON THE PERCEPTION OF STUDENTS OF THE FACULTY OF MANAGEMENT AND RURAL DEVELOPMENT REGARDING THE ROLE OF DIGITALIZATION IN THE TRAINING OF COMPETENCES NECESSARY FOR THE INTEGRATION OF GRADUATES IN THE LABOR MARKET

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***Abstract***

*Among the consequences of globalization are the liberalization of markets, the development of technology, etc. elements that are interdependent and that have direct effects on economic development, demographic and political development. In these conditions, modern education, as a factor promoting research and innovation, must face the new challenges related to the construction of a multifactorial education, the formation of new skills, new professional competences, Therefore, the current paper aims to analyze precisely the problems of the digital transformation of the educational space and the training of professional skills, among the students of the Faculty of Management and Rural Development (FMDR) with the aim of increasing their degree of integration on the labor market. The research methodology assumed, on the one hand, an analysis of the specialized literature regarding the importance of digitalization in the formation of the competencies of university graduates, and on the other hand, the measurement of the FMDR students' perception regarding these aspects. Data collection was carried out with the help of a questionnaire with a number of 15 questions, which was applied to FMDR students and answered by a number of 127 respondents. The data were processed with the help of statistical methods, and the results obtained were analyzed and interpreted, forming the basis of the formulation of conclusions that highlighted the importance that digitization has in the training of graduates' skills and in increasing their degree of integration on the labor market.*

**Key words:** *students' perception, digitalization, innovation, technology*

## INTRODUCTION

Globalization is a social, cultural, economic, political and legal phenomenon that has contributed to the development of the modern world, to progress and innovation [9]. Therefore, currently, there is also talk about a digital globalization that accompanies the development of technology, the mobility of the labor force, which thus contributed to obtaining new skills for graduates. All these changes still require major changes, including the modernization of education systems. In this field, there are a series of barriers such as: focusing on training skills that do not keep up with the current world, orientation towards outdated education systems, failure to adapt to modern teaching-learning means, etc. That is why, at the institutional level, there is a need for the development of new skills that will contribute to the adaptation of graduates to the labor market, an aspect that in the long term will contribute to economic growth and innovation. Or this cannot be achieved without the involvement of educational institutions in general, but especially of higher education, which acts as a spearhead in terms of obtaining a highly qualified workforce and which must adapt to the new requirements, collaborate with business environment and welcome new industries.

In this way, digital technologies become an engine of development, an engine of social change throughout the world, higher education thus having a decisive role and having to adapt in turn, but not without encountering numerous difficulties, and not only of an ethnic nature, but also of perception [14, 19]. Digitization is becoming a way of life today, it is part of our current life, and modern education must face more and more the demands of the young generation, which is a generation born and raised in a digital environment, a generation easily adaptable to modernization and technology changes [17]. At the level of the European Union, in its 28 states, there are over 100 policies that refer to digitization: transversal policies, educational policies and policies that refer to workplaces. There are also concerns found in the Digital Competencies Framework for Citizens (DigComp), which is structured in five areas, and which refers to 21 competencies. The five areas are: digital and information literacy; communication and collaboration; creating digital content; safety and troubleshooting.

Even if there were these concerns, what contributed at a rapid pace to the increase in the pace of development of digital skills was the Covid-19 pandemic. During the Covid-19 pandemic, the education system, like many other sectors of activity, had to adapt quickly and on the fly to the new conditions, because otherwise it would have risked closure [2, 8]. In this way, the pace of acquiring digital skills has increased. Digital skills presuppose the use of information and communication technologies for the purpose of information, communication and solving problems that belong to all areas of life, being included in the category of transversal skills, precisely because they allow the development of key skills (linguistic skills, mathematical skills, etc.) [12, 21]. Therefore, realizing the importance of digitization, the European Commission proposed in 2020 new objectives for the development of digital skills and competences, embodied in 12 actions that proposed quantitative objectives, a recommendation regarding education and sustainable professional training and a set of indicators through which it was aimed that by 2025, 70% of the adult population of the Union should have digital skills.

As far as Romania is concerned, as in the other member states of the European Union, there were concerns related to digitization that started before the Covid-19 pandemic. In 2016, the "Educated Romania" program was launched, a program that was followed by public debates that took place between 2016-2018. Although initially the program did not have a digitization strategy, as a result of the health crisis, it was necessary to face the new challenges on the fly. It is the Covid-19 pandemic that has led to the awareness of legislative gaps and to the highlighting of deficiencies regarding digital skills and the way of using technologies in education. This, although it is not specific only to Romania, but to all the countries of the European Union, even to all the countries of the world, is an important topic that must be discussed [22]. Eurostat data from 2019 showed that if at the level of the European Union, the share of young people aged between 19-24 with digital skills was 80%, in the case of Romania, their share was only 56%.

As in the case of the other member states, starting from 2020 Romania transformed digital education into a key objective of the teaching-learning-evaluation process, through which due importance was given to the acquisition of digital skills not only for students or young people, but for all those who they want lifelong learning [11].

A study developed by the Center for International Development and Cooperation Studies (IDC) that refers to digital skills in Romania shows that in terms of the business environment, over half of the companies believe that digitization will have a positive impact on the market, from the perspective the jobs they anticipate. Although they are not lagging behind in adopting modern IT solutions and technologies, which will lead to increased demand for digitally skilled people in the future. One of the biggest challenges, however, is finding people with both technological and social skills.

The vast majority of companies consider collaboration with academia to be the surest way to recruit people with digital skills. At the same time, the digital skills formed through personal use become a standard part of the Romanian employee's professional tools [5].

In addition to the role played by the specialized subjects from the analytical programs of the universities in the formation of digital skills, an important role also belongs to pedagogy, which in turn contributes to the formation of social skills [7, 13, 20].

It was found that the Covid-19 pandemic meant all over the world a period of rethinking teaching-learning-evaluation practices that had to adapt to the new conditions, had to acquire greater flexibility in terms of their application, have had to face some complex challenges, and to answer them in a short period of time [6].

Even if the COVID-19 crisis brought into discussion numerous opportunities related to digitization, it must be pointed out that it also highlighted the numerous risks related to the online environment, its security, etc. [1].

Pursuing the achievement of the objectives related to digitization and its role in the training of competences is a complex problem, which must be managed in an efficient way, by involving all the actors involved in this process, so that the results are the desired ones.

## MATERIALS AND METHODS

The research methodology involved both the study of the specialized literature and the realization of a quantitative research that used the structured personal survey as a data collection method. The tool for gathering information was the questionnaire applied to the students of the Faculty of Management and Rural Development.

The questionnaire included 2 parts, the first part having 3 demographic questions, and the second part having 15 questions with closed or open answers, regarding the students' perception of the need to digitize the educational process in order to increase the chances of integration on the labor market.

The use of closed questions had the role of facilitating the use of several items, supporting the respondent's memory, filtering the rest of the questions and allowing the statistical analysis of the answers [3]. Open questions were used to eliminate the risk of suggestibility [4].

The 15 questions were the following:

Q1-What are the devices you use for learning activities?

Q2-How many hours a day do you use digital devices?

Q3-How many hours a day do you use digital devices for learning activities?

Q4-How much do you use technology in the learning activity?

Q5-How much do you want to learn to use software or other digital resources in the learning activity?

Q6-What are the devices you have access to within the faculty?

Q7-How motivated are you to use digital technology in the learning activity?;

Q8- In what proportion is digital technology used in courses and seminars?

Q9-In what proportion do you use software or other digital resources in the learning activity at the faculty?

Q10-In what proportion did the subjects studied during college contribute to the development of digital skills?

Q11-Which of the following skills have been developed by the subjects you studied in college?

Q12-Did online teaching activities contribute to the development of digital skills?

Q13-Have you attended digital skills training courses organized by the university apart from those studied in the education plan?

Q14-Do you consider that digital skills are useful in finding a job?

Q15-How important do you think digital skills are for your future activity?

The questionnaire was applied between March and April 2022, and the response rate was 28.22% (127 students responded, 450 tests were sent). Sampling was subjective. The students gave their consent regarding the participation in the case study.

Data processing was carried out with the help of statistical methods, and conclusions were formulated based on the results obtained.

## RESULTS AND DISCUSSIONS

The questionnaires regarding the perception of the students of the Faculty of Management and Rural Development regarding the need for digitalization in the education system with the aim of increasing the chances of their integration into the labor market was sent to a number of 450 students. The number of those who answered and for whom the completion of the questionnaire could be validated was 127 students.

From Table 1, where the data obtained from the 3 demographic questions were centralized, it is found that 70.07% of the respondents are female, and 29.93% are male. Almost 97% of student respondents are between 19-24 years old. Out of a total of 127 respondents, 24% are students in their second year, 43% in their third year and 33% in their fourth year.

Table 1. Demographic information

| | Type | Frequency | % |
|---|---|---|---|
| Sex | Female | 89 | 70.07 |
| | Male | 38 | 29.93 |
| Age | 19-24 years | 123 | 96.85 |
| | over 24 years | 4 | 3.15 |
| Year of study | II | 31 | 24.40 |
| | III | 54 | 42.51 |
| | IV | 39 | 33.09 |

Source: own processing.

Base on the answers given to the 15 questions, of which 2 were questions with open answers and 13 with closed answers, the conclusions of the study could be formulated.

From the answers provided by the respondents to question no. 1: *What are the devices you use for learning activities?* we find that 88% of students use the phone in their learning activities, and 82% of them also use the laptop. None of them use the tablet for these activities, but 29% use the PC.

To open question no. 2: *How many hours a day do you use digital devices?* The answers varied from 2 hours to 8 hours. Thus, among the 127 respondents, most, i.e. 59%, use these devices 7-8 hours/day. At the same time, those who use the phone only 2, respectively 4 hours a day represent approximately 6% of the total respondents.

Of the total time spent using digital devices, the majority is dedicated to learning activities.

Thus, to question no. 3, the open answers showed that the time used for these activities varies from 1 hour to 6 hours. The largest share of students, i.e. 29% of the total, spend 4, respectively 5 hours with the aim of their school preparation. The lowest percentage spent by the respondents for the purpose of carrying out educational activities with the help of digital devices is 6%, i.e. by those students who allocate 1 hour, respectively 2 hours/day.

Table 2. Survey Questions (Q1–Q5) with responses

| Q | Survey Questions | Response (%) |
|---|---|---|
| 1 | What are the devices you use for learning activities? | Desktop – 29.4%<br>Laptop – 82.4%<br>Phone – 88.2%<br>Tablet – 0%<br>None of these -0.0% |
| 2 | How many hours a day do you use digital devices? | 2 hours – 5.88%<br>4 hours -5.88%<br>5 hours – 11.76%<br>6 hours – 17.65%<br>7 hours – 23.53%<br>8 hours – 35.3% |
| 3 | How many hours a day do you use digital devices for learning activities? | 1 hour – 5.88%<br>2 hours – 5.88%<br>3 hours – 23.54%<br>4 hours – 29.41%<br>5 hours – 29.41%<br>6 hours – 5.88% |
| 4 | How much do you use technology in the learning activity? | 0-25% - 0%<br>26-50% - 23.5%<br>51-75% - 35.3%<br>76-100% - 41.2% |
| 5 | How much do you want to learn to use software or other digital resources in the learning activity? | Very much – 58.5%<br>Much – 17.6%<br>Medium – 23.5%<br>Little -0.0%<br>Not at all – 0.0% |

Source: own processing.

According to the answers given to question no. 4: *How much do you use technology in the learning activity?* we find that this has an important place not only in the daily life of young people, but also in their learning activity. Thus, more than 76% of students predominantly use digital technology in the learning process (that is, in the proportion of 51-100%). None of the respondents appreciated that the use of technology is done in a proportion lower than 25%. This proves the necessity of using digitization in the learning activity, but to the same extent it must also be used in the teaching or evaluation activity. What was found, however, is that the new generations, although they are equipped with new cognitive abilities that have been developed following the intensive use of media technologies, are still faced with a substantial gap in terms of educational factors and which comes from the radical transformation of styles cognitive and social practices [15, 16, 18].

Another question referred to the students' desire to use software or other digital resources in the learning activity. The answers provided show that the students are aware of their importance. Thus, 59% of them want to use them very much, and 18% very much. None of the respondents appreciated that the use of digital tools would be of little or no use (Table 3).

Table 3. Survey Questions (Q6–Q10) with responses

| No | Survey Questions | Response (%) |
|---|---|---|
| 6 | What are the devices to which you have access within the faculty? | Wi-Fi – 64.7%<br>Desktop – 52.9%<br>Laptop – 41.2%<br>Smart board – 35.3%<br>Other devices – 11.8% |
| 7 | How motivated are you to use digital technology in the learning activity? | Very motivated – 58.8%<br>Quite motivated – 29.4%<br>Medium motivated – 11.8%<br>Little motivated – 0.0%<br>Not at all – 0.0% |
| 8 | In courses and seminars, digital technology is used in proportion to: | 0-25% - 17.6%<br>26-50% - 41.2%<br>51-75% - 11.8%<br>76-100% - 29.4% |
| 9 | In what proportion do you use software or other digital resources in the learning activity at the faculty? | 0-25% - 23.5%<br>26-50% - 35.3%<br>51-75% - 17.6%<br>76-100% - 23.5% |
| 10 | In what proportion did the subjects studied during college contribute to the development of digital skills? | 0-25% - 23.5%<br>26-50% - 29.4%<br>51-75% - 17.6%<br>76-100% - 29.4% |

Source: own processing

From the answers provided by the FMDR students, we find that during the teaching-learning-evaluation activities, they have access to a varied range of digital devices (65% use the WiFi network provided, 53% use PCs, 41% laptops, 35% use the existing smart boards in the classrooms, and 12% also use other devices. They also appreciate that they are motivated and encouraged in the use of digital technology (Table 3).

Thus, 80% of the respondents consider that they are *very motivated* or *fairly motivated*, but no one is a *little motivated* or *not at all motivated* in using technology in the learning process (Table 3).

From question no. 9: *In what proportion do you use software or other digital resources in the learning activity at the faculty?* it results that although they are used in a proportion greater than 75% by 24% of the students and in a proportion between 51-75% by a share of 18% of them, there are also 24% of respondents who use software in a proportion less than 25% (Table 3).

It can be observed that there is a direct correlation between the year of study and the use of digital educational resources, because in the category of respondents who appreciate that they use these resources in a lower proportion (0-25%), there are second year students, who according to of the analytical program study basic subjects, with a technical character, while the students of the III and IV years, who study economic subjects (Accounting, Project Management, Investment Efficiency, Simulated Enterprise, etc.) appreciate that the proportion of using social media is higher.

To the question with no. 11: *Which of the following skills were developed by the subjects you studied in college?* we find that almost 77% of the students appreciate that they have acquired data analysis and interpretation skills. They also developed skills related to the creation of digital materials (70.6%), information (use of databases, specialized websites, etc.) or research (for the preparation of projects, for the completion of the bachelor's thesis, etc), the weights being 58.8% each (Table 4).

*Are you asking if the implementation of online didactic activities contributed to the development of digital skills?* we find that the highest percentage of students, i.e. 41.2%, consider that these skills have been developed quite a lot. A share of 35.3% of students appreciates that these skills have been developed a lot, while approximately 18% appreciate a moderate contribution to the formation of skills, and 6% a reduced contribution (Table 4).

Table 4. Survey Questions (Q11–Q15) with responses

| No | Survey Questions | Response (%) |
|---|---|---|
| 11 | Which of the following skills have been developed by the subjects you studied in college? | IT skills – 52.9%<br>Data analysis and interpretation skills – 76.5%<br>Creating digital material – 70.6%<br>Information skills – 58.8%<br>Research skills – 58.8% |
| 12 | Did online teaching activities contribute to the development of digital skills? | IT skills – 52.9%<br>Data analysis and interpretation skills – 76.5%<br>Creating digital material – 70.6%<br>Information skills – 58.8%<br>Research skills – 58.8% |
| 13 | Have you attended digital skills training courses organized by the university apart from those studied in the education plan? | Yes – 17.6%<br>No – 82.4% |
| 14 | Do you consider that digital skills are useful in finding a job? | Yes – 94.1%<br>No – 5.9%<br>I do not know – 0.0% |
| 15 | How important do you think digital skills are for your future activity? | Very useful – 82.4%<br>Quite useful – 17.6%<br>Medium – 0.0%<br>Slightly useful – 0.0%<br>Not useful at all – 0.0% |

Source: own processing.

Although digital skills training courses were regularly organized within the USAMVB Counseling Center, only a small part of the FMDR students followed them (17.6%, but this category also included courses that had other organizers).

Regarding the extent to which FMDR students consider that digital skills will be useful to them in finding a job, only approximately 6% of them consider that they are not useful to them, the rest considering that these skills will increase their chances.

To question no. 15: *How important do you think digital skills are for your future activity?* we find that approximately 82% of the respondents considered that they were very useful, and the remaining 18% considered that they were quite useful (Table 4).

The respondents are aware of the fact that modern society requires the possession of these digital skills, which, as I said earlier, are no longer just necessary, but mandatory.

However, digital technologies have other advantages that must be remembered: they contribute to people's access to information, dematerialize spatio-temporal boundaries and contribute to the reduction of social or situational differences by creating new forms of communication or accelerate the process of globalization, as observed by Marshall McLuhan since 1961 through paradigm of the "global village" [10]. But let's not forget forms of exclusion, poverty or digital gap, which accentuate the old inequalities and thus require a transition from a protectionist approach to a dialogic one, centred on understanding how the young generation adopts, uses and interprets digitalization.

## CONCLUSIONS

The Covid-19 pandemic was a good moment for reflection and development of trends related to the development of professional skills, especially digital ones that make a company's employees remain relevant on the labor market.

The unprecedented situation of this pandemic highlighted the discrepancy between the digital skills possessed by employees and those needed, which brought the issue of digitalization even more into discussion.

The future of the labor market is influenced by the development of digital skills of graduates, by their integration in the lifelong learning process.

The respondents appreciated that the university studies within the FMDR contribute to the development of digital skills and agreed that their possession is vital for increasing their competitiveness and professional insertion capacity.

In order to increase the degree of development of digital skills, we consider that it would be useful to develop partnerships between the main actors involved in the progress of the educational process: universities, the private sector, public institutions. These partnerships must contribute to the development of sustainable public policies for the labor market, which offer real opportunities to the younger generations.

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# ECONOMIC ASPECTS OF QUINOA TRADE BETWEEN PERU AND THE EUROPEAN UNION

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***Abstract***

*The paper points out the quinoa trade between Peru and the European Union regarding selected economic issues of quinoa production and prices in Peru and import into the EU. Quinoa is known as superfood due to the high level of protein, fibre, micronutrients, and all amino acids. This caused an increased interest in its consumption in the EU which resulted in rising prices. High quinoa prices have motivated farmers in different parts of the world to try producing quinoa that is traditionally home to areas in South America. The increase in the quantity of quinoa offered led to its fall in prices. Quinoa price volatility creates uncertainty for Peruvian farmers and traders, for whom quinoa is one of the main commodities. The article focuses on the development of quinoa production and prices in Peru, a country that is one of the main producers of quinoa in the world at a time when quinoa has become a popular superfood. During this period, imports of quinoa into the EU, which is a major trading partner of Peru in relation to the quinoa, also increased. Based on the assessed economic situation in the quinoa market between Peru and the EU, the authors of the article are looking for tools that could make it easier for Peruvian farmers to be successfully established in the EU market, despite the high interest in growing this commodity in different parts of the world.*

**Key words**: *quinoa, trade, prices, Peru, European Union market, economic aspects*

## INTRODUCTION

Quinoa (*Chenopodium quinoa*) is an Andean crop of great importance in supplying essential amino acids, protein, starch, and ash [32]. It is gluten-free and has twice as much protein as maize, barley and wheat [30], [33] and more micronutrients than wheat, rice or barley [24]. In 21st century, quinoa has earned special attention worldwide not only due to these nutritional and health benefits but also due to its ability to adapt to contrasting environments, including nutrient-poor and saline soils and drought-stressed marginal agroecosystems [14]. Moreover, quinoa is also resistant to cold [2]. Although Peru and Bolivia are still the most important global exporters, quinoa cultivation has spread to more than 120 countries. Production outside the Andes is increasing, and farmers from Peru and Bolivia face a scenario of new concerns and competitors [1]. However, variability of climatic conditions, such as hails, frosts, droughts, floods, or high temperatures, determine total production levels [34], [11], [35], [5], [22]. Moreover, the environmental conditions and location can affect the nutritional parameters (e.g. the amino acid profile, the protein content, the mineral composition) [29], [13]. This means that even though quinoa is a relatively undemanding plant, it is not possible to grow it everywhere. On the other hand, the natural and environmental conditions alone will not ensure the primacy in quinoa cultivation for the Andean countries in the future without improving the economics of quinoa cultivation. In the Andean countries, quinoa is produced by small-scale producers (with land acreage up to 10 ha), and due to their scale of production, they lack the capacity to export or commercialize the product in larger markets; the bargaining power to negotiate better prices and other conditions; and the ability to meet the quality and safety standards of larger and more demanding markets [10].

The aim of the article is to find out tools that could make it easier for Peruvian farmers to be successfully established in the EU market, despite the growing interest in growing this commodity in different parts of the world.

## MATERIALS AND METHODS

We used the statistical data relate to the quinoa international trade from trade statistics database of the EU and Agriculture Ministry of Perú from 2013 - 2021. Moreover, we used the appropriate normative EU legal acts relating to the trade between Peru and the EU and relevant political documents as well as scientific publications on quinoa.

The statistical data related to the quinoa import (quantity and value of quinoa import from third countries, mainly from Peru in the EU in 2012-2021) are presented in the figures with the use of methods of basic statistical analysis and statistical induction methods (non-parametric Kruskal – Walis test) for evaluation of statistically significant differences among the quinoa prices from the various part of the world. For the legal and political documents, jurisprudence methods such as logical and formal legal methods were used and sociological methods to find the legislative and political tools of supporting farmers from Peru to establish them on the European market.

## RESULTS AND DISCUSSIONS

### Quinoa production and market in Peru

Quinoa was domesticated in the Andean region of South America (mainly in Bolivia and Peru around Lake Titicaca) 5,000 years ago [7] by the Aymara and Quechua, pre-Inca civilizations [15] that traditionally use quinoa for nourishment. Quinoa (its seeds) was originally used only to feed animals. Later, people began to use quinoa also for their own consumption. Moreover, the Inca civilisation considered quinoa a sacred food [12] and was used for their religious ceremonies. With the arrival of the Spanish conquerors, quinoa was replaced by other crops and fell into oblivion. Quinoa was rediscovered in the 70s of the 20th century. By 2013, which was the international year of quinoa, the production and consumption of quinoa increased exponentially [4]. However, quinoa was widely consumed in the EU long before. The European Commission, in its Novel Food Catalogue, stated that quinoa does not require authorisation under the Novel Food Regulation (EC) 258/97 as it is widely consumed and to a great extent before the legislation came into force on 15th of May 1997 [28]. Nowadays, quinoa has gained recent attention as a ‘superfood’ [29] because it is gluten-free, and contains a high level of protein, minerals, fibre, antioxidants and vitamins [37]. Quinoa has good quality lipid, starch and mineral compositions and is rich in saponins [19], [31].

Quinoa is the seed from the *Chenopodium quinoa* from the amaranth family. The classification of quinoa was first made from the plant's colour and seeds [18]. Nowadays, in addition to the traditional colours (white, red, and black), there are purple, pink, grey, orange, green, and yellow colours of quinoa seeds. Different types of quinoa exist in the Andean region whose characteristics vary among agroecological zones, e.g. the Altiplano (northern Andean highlands); the shore of salt lakes (southern Andean highlands); the inter-Andean valleys; arid zones and dry conditions (eastern Andean highlands); high altitudes and cool climates; coastal regions and near the sea; jungle and tropical zones; high rainfall and humidity zones [6].

Quinoa tolerates a wide range of acidic soil conditions [18] and a wide range of temperatures from around –8°C up to + 38°C [6]. Quinoa is frost resistant, but also before flowering, because the frost may occur significant damages on the yields [17]. The other special characteristics of quinoa are drought resistance and adaptation to saline and sandy soils, enabling quinoa cultivation in deserts' extreme conditions [6]. Quinoa is able to be cultivated even in regions where the annual rainfall is in the range of 200–400 mm [36]. The quinoa seed collection and purification in the Andes is time and labour-intensive and is carried out mainly manually by traditional methods [8]. Peru's average quinoa yield per hectare of land was 1.40 tons during 2013 - 2021. It ranged from 1.16 tons in 2013 to 1.68 tons in 2014. In 2021, the average quinoa yields were 1.57 tons per hectare of land [26]. In 2013, quinoa was cultivated on an area of 45,000 ha. After the international year of quinoa, the acreage of land for quinoa cultivation has been increased by half. The acreage of land for quinoa cultivation ranges from 61,721 to 69,303 between 2014 – 2021.

Peru is the world's largest producer of quinoa and produces more than half of the world's supply. The second largest producer is Bolivia that produces a third of the world's production. One of the most important quinoa trade partners of Peru and Bolivia is the European Union. A third of the Peru´s quinoa production is imported into the EU (Fig. 1).

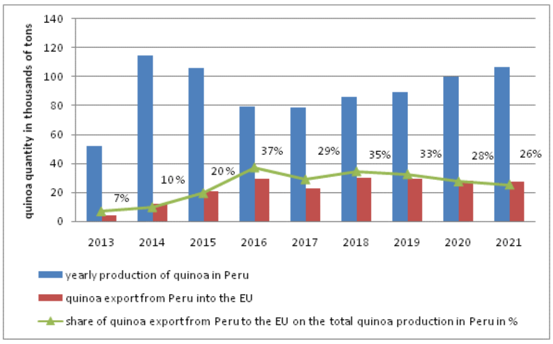


Fig. 1. Quinoa production in Peru 2013- 2021
Source: [9, 26].

The international year of quinoa (2013) caused an increased demand for quinoa on the international market what contributed to tripling the quinoa prices on the world markets.

However, the quinoa prices fell in 2015 due to increasing supply from Peru and Bolivia on the one hand and from other countries on the other hand. Quinoa cultivation has spread to more than 120 countries that were encouraged by the high prices and increased demand to start cultivating quinoa. The price development is documented in Fig. 2.

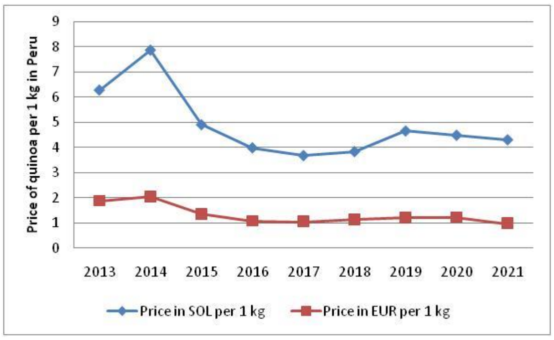


Fig. 2. Quinoa prices in Peru in 2013- 2021
Source: [9].

This situation has affected quinoa consumption in Peruvian households and their production decisions [16]. According to [21] the rapid increase in quinoa prices following the increased international attention to quinoa as a “superfood” and the increased international trade in quinoa created concern about the welfare effects for (often poor) people in Andean regions, where quinoa originates from. According to [17] this brings new competitors to the Andean region, where quinoa is produced in both traditional and intensive production systems. Therefore, the main challenges for Peruvian farmers are volatile yields, low levels of technology, fragile ecosystems and unclear rules on sharing the benefits of conserving Andean genetic resources. One solution to these challenges could be the EU's quality policy, as Peru is a major partner in the quinoa trade. Moreover, European consumers tend to attach more importance to food quality, leading to increased demands for agricultural products or foodstuffs. The EU has adopted Regulation no. 1151/2012 on quality schemes for agricultural products and foodstuffs that should provide producers with the right tools to identify and promote products with specific characteristics while protecting them against unfair practices. The citizens of the third countries can also use these tools for delivering products to the EU. There are three important tools related to the agricultural products and food: protected designations of origin, protected geographical indications and traditional specialities guaranteed. The first and second terms could be used when identifying a product originating in a specific place, region or country whose

-quality or characteristics are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors; and the production steps of which all take place in the defined geographical area (designation of origin).

-whose given quality, reputation or other characteristic is essentially attributable to its geographical origin; and at least one of the production steps of which take place in the defined geographical area (geographical indication).

The results of [29] revealed that several nutritional parameters such as the amino acid profile, the protein content, the mineral composition and the phytate amount in the seeds depend on the location and cultivar [13] presented a significant influence of the environmental conditions on the nutritional and physiological characteristics of quinoa seeds, which affects overall seed quality. It means that the specific Andean location is able to influence the quality, characteristic or reputation of quinoa to receive the protected designation of the EU.

The third mentioned tool - traditional specialities guaranteed - is established to safeguard traditional methods of production and recipes by helping producers of traditional products in marketing and communicating the value-adding attributes of their traditional recipes and products to consumers. It means that the traditional methods of production and recipes for cultivation and production of quinoa can be maintained and protected by the scheme of the EU quality policy. In addition, products under the quality scheme of the EU are considered by EU consumers to be of higher quality and therefore a higher price can be expected. Moreover, the quality of quinoa can be supported by the nutrition claims that can be used for quinoa [20].

**Peruvian Quinoa import into the European Union and Slovakia**

The import of quinoa to the EU started to develop more intensively in 2012. After the economic crisis, the people in the EU have been interested in healthy food, and quinoa has become a very popular superfood. The import of quinoa from South America, mainly Peru and Bolivia, has increased by more than 100%. Statistics on quinoa imports were unavailable before 2012, but 207,000 tonnes of quinoa were imported into the EU between 2012 and 2021 from over the world. Of it, 85.29% was imported from Bolivia and Peru. The import of quinoa from these two countries increased during the followed period 2012 – 2021. One of the measures to support the quinoa import to the EU was the agreement concluded between the EU and its countries on the one hand and Peru and Bolivia on the other. Generally, the common custom tariff for quinoa imported into the EU from the third countries is 37 Eur per ton. However, the EU and Peru together with Colombia had concluded the trade agreement between the EU and its Member States, of the one part and Colombia and Peru, of the other part, which is applied in Peru since 1st March 2013 and in Colombia since 1st August 2013 and Ecuador accessed to this Agreement since 1st January 2017 (L354/3). According to this agreement, the tariff preference for Peru is zero percentage. The development of quinoa import to the EU in 2012-2021 is documented in Figure 3.

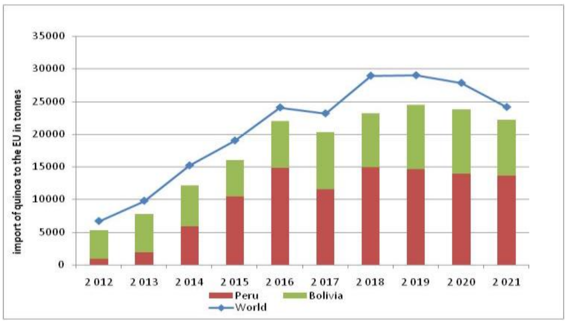


Fig. 3. Quinoa import to the EU in 2012- 2021
Source: [9].

According to Figure 3, the most quinoa is imported from Peru (on average 44.63 %) and Bolivia (39.81%) to the EU in the period 2012 – 2021. Only 15.56 % of quinoa import is from other countries of the world, such as Ecuador, Brazil, Chile, Colombia, Mexico, Canada, USA, Russia, India, China, Egypt, Israel, South Africa, Zambia, Turkey, Norway, Switzerland, or United Kingdom.

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After quinoa became a popular superfood, its prices on the European market rose (Figure 4). The average imported prices of quinoa were very similar (slightly lower) to the prices of quinoa imported from Peru or Bolivia to the EU; however, there is no statistically significant difference.

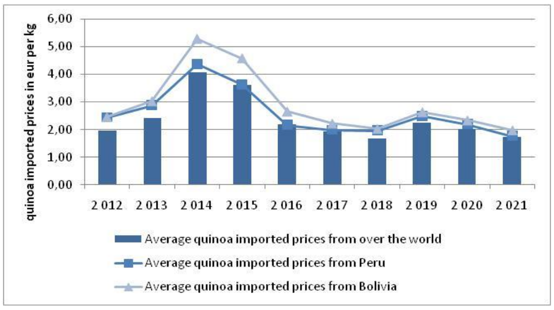


Fig. 4. Quinoa imported prices to the EU in 2012- 2021
Source: [9].

Quinoa has become most popular in the Germany, Netherlands and France which covered 63.25% of quinoa import in 2021 from over the world (Figure 5). Slovakia imported only 0.09 % of all imported quinoa in the EU.

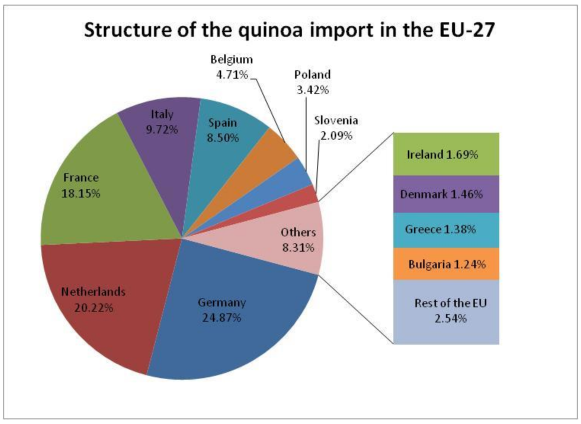


Fig. 5. Structure of the total quantity import of quinoa in the EU-27 in 2021
Source: [9].

Peru was the most important importer of quinoa into the EU in 2021. Of all quinoa imports, Peru covered 56.63% of the imported quinoa from over the world. Slovakia imports quinoa only from Peru. However the quantity of imported quinoa to Slovakia is still very low compared to the other EU countries (0.16 % of all quinoa imports from Peru to the EU internal market in 2021). The structure of import from Peru to the particular member states of the EU in 2021 is documented in Figure 6.

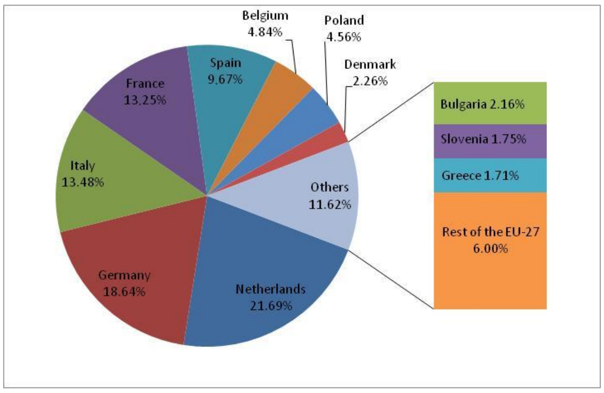


Fig. 6. Structure of the Peru quinoa import in the EU-27 in 2021
Source: [9].

Quinoa was imported first time to Slovakia in 2015 (40 tons from Peru). In the period 2016 - 2021, quinoa imports fell by almost half (Figure 7). All quinoa is imported to Slovakia only from Peru, although the EU-27 also imports quinoa from other countries of the world, especially from Colombia and Ecuador.

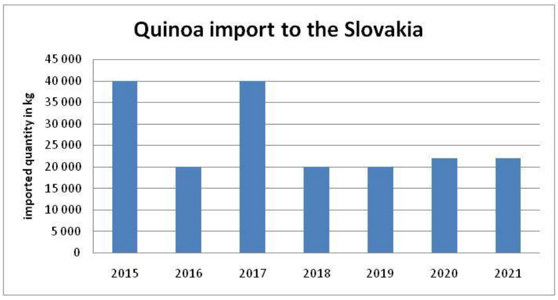


Fig. 7. Quantity of imported quinoa from Peru to Slovakia
Source: [9].

The imported prices of quinoa from Peru are slightly higher than the average world prices of quinoa. On the other hand, the quinoa prices imported from Peru to Slovakia are slightly lower than the quinoa prices imported from Peru to EU-27 (Figure 8). In 2015- 2021 the average quinoa prices in Slovakia ranged from 1.64 EUR per 1 kg to 3.14 EUR per kg, while quinoa prices in the EU-27 imported from Peru ranged from 1.76 EUR per 1 kg to 3.62 EUR per 1 kg. However, there are no statistically significant differences between the compared prices of quinoa.

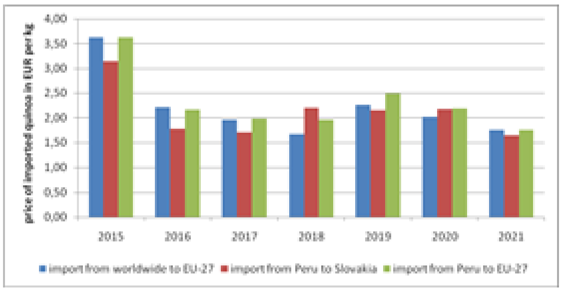


Fig. 8. Price comparison of imported quinoa to the EU-27 and Slovakia
Source: [9].

Despite quinoa's price volatility during the following period, Peru has become the most important trade partner of the EU concerning quinoa import (Figure 8). However, stable quinoa prices are important for small Peruvian farmers who cultivate the quinoa by traditional methods on a very small acreage of land. In fact, there are up to 65% of small farmers in the Peru, who manage an area of 2.49 ha on average; of which they grow quinoa only on an area with an average of about 0.51 ha. The average annual quinoa production of a small farmer is approximately 314 kg. Only 35% of medium-sized farmers in Peru farm on an average of 3.85 ha, of which they use an average of 1.33 ha of land for quinoa production. The average annual quinoa production of a medium-sized farmer is approximately 1089.3 kg [25].

However, if we consider minimum wage in Peru in 2022 (1,025 SOL per month or 12,300 SOL per year; if 1 EUR is 4 SOL on average, then the minimum wage is 3,075 EUR per year or 256 EUR per month), the quinoa price (4.31 SOL (1.08 EUR) per 1 kg in 2021 and 3.50 SOL (0.875 EUR) per 1 kg as a minimum price during the period 2013 – 2021) and yields from one hectare of land (1.4 tons per 1 ha on average during 2013 – 2021 and 0.4 tons per 1 ha according to [1]), for quinoa cultivation, the Peruvian farmers need land of acreage from 2.04 ha in the best case of prices and yields to 8.79 ha in the case of 3.50 SOL per 1 kg and yields 0.4 tons per 1 ha of land. According to the data [25], only 35% of farmers would be able to receive a minimum yearly wage from quinoa cultivation and only in the case of the best conditions of yields and prices. In general, the average yields from one hectare of land are 1.4 tons; however, in 2015, yields of quinoa ranged from 0.4 to 1.1 tons per one hectare of land [1]. Moreover, the purchase price of quinoa from very small farmers could be lower than the average quinoa prices on the market due to the small quantity they supply. Therefore, the small Peruvian farmers need to increase their negotiate power in relation to the quinoa prices by establishing their farmers associations which will be able to stabilise the purchase prices for small farmers. Moreover, such associations would be able to protect business interest of their members and provide them various services necessary for their business, such as storage of quinoa when the demand is decreasing, marketing or administration advices, obtaining certification of origin, traditional specialty guarantee, or regional trademark, organisation of educational or training courses, extension services together with agrarian universities, advices on increasing the quality of production, sale promotion or processing promotion, because selling quinoa may not be the only solution for Peruvian farmers. The added value of quinoa could be increased by the production of traditional, regional or new modern products, e.g. quinoa flour and bread, quinoa crisps, quinoa sauces, quinoa powders, and quinoa snacks. But small farmers would not be able to produce the final quinoa products without the special help of farmers' associations. Further, adding value to quinoa and its final products can be achieved in connection with the development of services, mainly tourism, rural tourism or agro-ecotourism, with the presentation of history, tradition and cultures associated with quinoa, e.g. [3] or [27]. Moreover, farmers' associations would be able to support the export not only quinoa seed but also the final products of quinoa on the world markets. However, such farmers' associations (mainly on the regional, national or international level) need to be familiar with the legal export regulations in relation to quinoa. In the EU, despite the conclusion of an agreement with Peru that eliminated quinoa tariffs, there are many EU legal acts that importers of quinoa from the third countries to the EU must follow. There are food safety and quality requirements (HACCP, phytosanitary regulations, limits for agro-chemicals, contaminants, microbiological criteria, GMO, food law), food labelling, organic labels and nutrition and health claims, food packaging and shipment. Food products, including quinoa, are relatively often repacked to be in harmony with the EU legislation. But it increases the additional costs in connection to waste management [23]. In any case, it is very difficult to be familiar with all different EU legal regulations and their amendments. If it is not possible to simplify this legislation, the importers would certainly appreciate a manual with all relevant legal acts in one place related to the quinoa import to the EU that would be regularly updated. The website of the European Commission Access2Markets is a particular help for foreign trade partners [9].

## CONCLUSIONS

Quinoa, considered a superfood of 21st century, is a traditional pseudo cereal of inhabitants in the Andean rural areas. It is an undemanding crop; therefore, there are attempts to grow it in other parts of the world. Nevertheless, Peru and Bolivia remain the largest producers and exporters of quinoa in the world and important trade partners in quinoa for the EU-27. However, in order to maintain the lead in the still traditional cultivation of quinoa in these countries, it would be appropriate to consider using the quality schemes provided by the EU in the form of protected designation of origin, geographical indications or traditional specialities guaranteed. In addition, to stabilize prices for farmers, it is necessary for farmers to increase their bargaining power in the market by building farmer associations which would be able to represent their interests in the market, support their business intentions and help with the foreign legislation, mainly the very strict EU legislation. Despite the conclusion of an agreement with Peru that eliminated quinoa tariffs, there are many EU legal acts that importers of quinoa from the third countries to the EU have to follow. In any case, it is very difficult to be familiar with all different EU legal regulations and their amendments. The website of the European Commission Access2Markets is a particular help also for Peruvian exporters of quinoa.

On the other hand, quinoa is also considered fundamental in guaranteeing food security and eradicating hunger. Therefore Andean countries should not forget about their own consumption and promotion of healthy eating when exporting quinoa and placing it on world markets. To improve quinoa consumption by nationals, Andean countries can promote national programs (e.g. school meals) or recovery of traditional ways of consumption or promote innovative products that include quinoa as an ingredient [1]. It should be the route that will ensure the preservation of the Andean countries' cultural and gastronomic traditions and cultural heritage as the original growers of quinoa. This fact can attract tourists, experts in gastronomy and food industry, which will lead not only to the growth of tourism in these rural areas, but also to the support of the production and sale of local products with higher added value, the final price and, finally, a higher income for local farmers.

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# THE CHALLENGES OF THE AGRICULTURAL SECTOR OF THE REPUBLIC OF MOLDOVA IN THE YEAR 2022

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***Abstract***

*At the same time, a negative impact on consumers is the very high inflation in the Republic of Moldova, which negatively affects the social environment and is caused by the increase in food and energy prices. Similarly, agriculture being an important economic sector for our country, this year has shown a lower productivity than the rest of the economy. Also, national economic agents, facing logistics problems, have generated increases in transport costs for exports from the Republic of Moldova. The aim of the research is to analyze the changes in the agricultural sector in the year 2022 compared to previous years and their impact on the country's population and food security, highlighting vital needs and how to respond to new challenges in the social and economic sphere. The research was carried out based on data provided by the National Bureau of Statistics, the National Bank of Moldova, the World Bank, the National Energy Regulatory Agency and the Food and Agriculture Organization of the United Nations using analytical, synthetic, tabular and graphical methods. On the basis of the research carried out, it was found that the impact of the crisis caused by the multiple changes in the agricultural sector poses a threat to the national economy and to the standard of living of citizens, but these obstacles force the development of the agro-industrial sector and its increased adaptation to the situation created and provides first of all for the development of the infrastructure for production, post-harvesting and processing, which is at an early stage of development and has been influenced by the presence of cheaper raw materials from import.*

***Key words***: *agricultural sector, inflation, quality of life, price increase*

## INTRODUCTION

The agri-food sector in the Republic of Moldova is one of the basic branches of the national economy, with agri-food products accounting for about half of the country's exports. The main branches of regional products are: cereals and their derivatives, the wine industry, sugar, fruit and vegetable preserves, natural juices, ether oils, etc. This is due to favourable climatic conditions for the development of agriculture. Most of the agricultural production is of plant origin, constituting about 90% of the total production volume. The agricultural potential of the Republic of Moldova can fully cover the demand on the domestic market. However, the decline in the agricultural sphere in recent decades has caused a multitude of economic problems, such as the non-value of available resources (especially agricultural land), lack of jobs and qualified human resources, migration of the population from rural areas, low use of new technologies for growing and processing agricultural production. All these impediments have a negative impact on the degree of satisfaction of domestic demand for agri-food products and on penetration of external markets [35].

For all countries, including Republic of Moldova, agriculture has been, is and will remain the support of human existence and is therefore the most powerful factor influencing economic and social stability. In our country agriculture is also the backbone of the national economy [3, 33].

The results of investment activity at the macroeconomic level are reflected in the growth of revenues of the national budget, the increase in employment of the population, the provision of stable incomes for citizens of the state. However, it should be mentioned that the development of investment activity is determined by the investment attractiveness of the economy of the state or its sectors[34].

The Republic of Moldova is undergoing continuous transformation, being directly affected by regional and global events: rising energy and food prices, due to hostilities in the region, the reform of value chains and climate change affecting agricultural production [28].

Being dependent on energy and inputs in all agro-food sectors from import, the logistics of exporting production is not adequate to the high demands.

In consequence, production costs increased, agricultural production declined a with a knock-on effect on export indicators and results, since more than 50% of Moldova's exports are of agri-food products.

Inflation increased from 18.52% in February to 33.55% in August 2022, according to data provided by the National Bank of Moldova.

This has automatically generated a wave of price hikes for goods and services that have been deeply reflected in the living standards of Moldovan citizens, but has also strongly affected the confidence of foreign investors to bring their money to the country. In addition, exports to eastern markets were also affected, due to the restrains of access to them caused by the hostilities in the region [2].

A recent report by the Food and Agriculture Organization of the United Nations states that the world is moving away from meeting the goals of eradicating hunger, food insecurity and malnutrition in all its forms. Increasing exposure to underlying factors (conflicts, extreme weather events and economic shocks), high nutritional costs and growing inequalities will continue to challenge food security and nutrition. This trend can only be reversed by transforming and strengthening the resilience of agri-food systems and making them a cheaper and healthier source of nutritious food that is affordable for all in a sustainable and inclusive way [8].

## MATERIALS AND METHODS

In this paper, research was carried out based on data provided by the National Bureau of Statistics, the National Bank of Moldova, the World Bank, the National Energy Regulatory Agency and the Food and Agriculture Organization of the United Nations.

In order to analyze the current state of affairs in agri-food sector, methods such as comparison, graphs, logical and synthetic analysis were used.

In order to determine the net effect of rising production costs and increased input costs prices, an analysis of the average cost structure for several years before the year 2022 and for the current year was carried out.

## RESULTS AND DISCUSSIONS

Following the hostilities in the region, at the end of February 2022, several consignments of food, plant protection products and mineral fertilizers destined for the Moldovan market were blocked on the territory of the neighbouring state or redirected to other states [29].

This unpredictable situation has led to a number of problems, including the impossibility of products destined for domestic consumers to enter the country on time, generating additional costs for national economic operators and causing the planned supply deadline to be missed [13].

Ukraine is Moldova's fourth largest trading partner in terms of volume of products, after Romania, Belarus and Russia, trade with this country has been halted since the outbreak of the conflict and the most important products, especially agri-foodstuffs, in demand there have been blocked [25].

As a result, average consumer prices on the Moldovan market have started to rise, some products are at risk of shortages, and the rush for supplies is becoming one of the hot topics among people. According to experts in the field, Moldova's gross domestic product could fall by 5% due to the hostilities in the neighbouring country [15].

The market of the Republic of Moldova, with close economic ties to both Ukraine and Russia and Belarus, started to be deeply affected. The transit of the exported of the Republic of Moldova to the markets of the Russian Federation and Belarus, is practically impossible at the moment [14].

In addition to falling export revenues, Moldova is also facing the fact that many goods previously imported from Ukraine, including food, have stopped being delivered. This has diminished the capacity of the Moldavian market to cover consumers' needs and imposed to the authorities to set up a new strategy for the coming period.

According to statistics, about 20-22% of all food imports into Moldova come from Ukraine, which has been the country's main supplier of food products. Among the main import items that have suddenly become unaffordable or whose deliveries have stopped are: dairy products, certain vegetables, animal feed, confectionery, bakery products and salt.

In 2021, the absolute poverty rate in the Republic of Moldova reached 24.5% of the country's population, with considerable differences between rural and urban areas, accounting for 32.8% in rural areas and 11.9% in urban areas [26].

Food security remains a real problem for about 10% of the population, who were in extreme poverty in 2014-2020 years, a situation that indicates a lack of resources to procure an adequate food basket. In rural areas the risk of extreme poverty is four times higher than in urban areas. At the same time, lonely elderly people and households with headed by people with lower levels of education and whose main source of income comes from agricultural activity. Widespread price increases in 2021 and inflationary risks are putting great pressure on household budgets and increasing food insecurity (Table 1). In 2022, expenditure on food and non-alcoholic beverages could reach 48.8% of the total in rural households and 41.9 in urban households [28].

Table 1. Consumption expenditures of population by purpose of expenditures and area, 2019-2021

| Destination of the expenditure | Rural | | | | Urban | | | |
|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2021 | 2022 | 2019 | 2020 | 2021 | 2022 |
| **Consumer expenditure, total, MDL** | 2,336 | 2,331 | 2,676 | 3,108 | 3,469 | 3,489 | 3,971 | 4,575 |
| **Food and non-alcoholic beverages, %** | 44.5 | 47.2 | 48.3 | 48.8 | 36.6 | 39.8 | 41.1 | 41.9 |

Source: National Bureau of Statistics [24].
Note: for the year 2022 are the forecasts of the authors of the National Development Strategy "Moldova 2030".

The level of self-sufficiency in the main types of agricultural products calculated on the basis of the balance of food resources and their use characterizes the country's food security and shows that the level of self-sufficiency in some types of agricultural products for 2021 covered the country's domestic consumption, in particular: in cereal crops (excluding pulses) including products derived from them - by 2.2 times and in fruit - by 2.6 times. At the same time, for potatoes, vegetables, meat and milk the level of self-supply was below 100%, i.e. for potatoes - 85.1%, vegetables - 79.5%, meat - 73.9%, milk - 66.0% [31].

Although food availability is not a significant challenge for the Republic of Moldova, as the food needs of the population are largely covered by domestic production and the gap between availability and needs is provided by imports, a significant concern for the Government is the volatility of agricultural production, as well as the instability of food supply, largely caused by the severe droughts that affected the country in 2012 and 2020, with devastating effect on the entire agricultural sector, the COVID-19 pandemic, as well as the hostilities in the region [10].

The fact that the Republic of Moldova is in close proximity to the conflict zone, the trade links with the affected states and the implications on import and export logistics, has further amplified the negative impact of the international context on the country's agriculture and food security.

A serious problem for agricultural producers is the disparity of prices that occurs between agricultural products and goods and services purchased by agricultural units, and also between the producers’ sale prices and those charged in the retail network [6].

In the context of complex efforts to increase profitability, measures are required to diagnose on the one hand the costs of production, and on the other - the commercial policy of the company with reference to the selling prices of agricultural products. The setting of sale prices must attract as wide a

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segment of buyers as possible, after which, depending on the evolution of the supply - demand ratio, the entity can choose the most appropriate strategy [37].

In the Republic of Moldova, food prices have been rising since mid-2021, but the hostilities in the region have put even more upward pressure on food prices, especially for crops, for which Ukraine is the main exporter (wheat, oilseeds, maize).

According to data from the Food and Agriculture Organization of the United Nations, food prices have seen a significant increase compared to the period before the COVID-19 pandemic [1], which saw an increase of more than 50% in food prices, 126% - oils, 69% - cereals, 18% - meat, 25% - sugar, 34% - dairy products (Fig. 1).

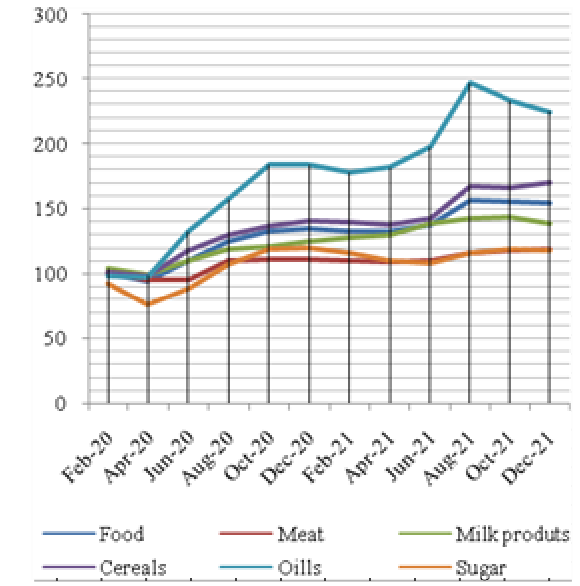


Fig. 1. Monthly food price index, % (2014-2016 = 100)
Data source: FAOSTAT [9].

For many countries of the world, agriculture is a basic component of the national economy, which plays an important role in providing income and reducing poverty. For the Republic of Moldova too, agriculture is the branch in which most of the rural population is engaged and which remains a significant source of income.

Specialization in high value added production represents an important indicator in terms of future development, but additional factors are needed to be taken into account for increasing their sustainability, like age of farmers, level of education and specialized studies in the field, modernization of farming activities and rationalization or the working time [36].

However, the share of agriculture in Gross Domestic Product (GDP) has been declining for some years, but is still significant and constitutes about 10% (Fig. 2).

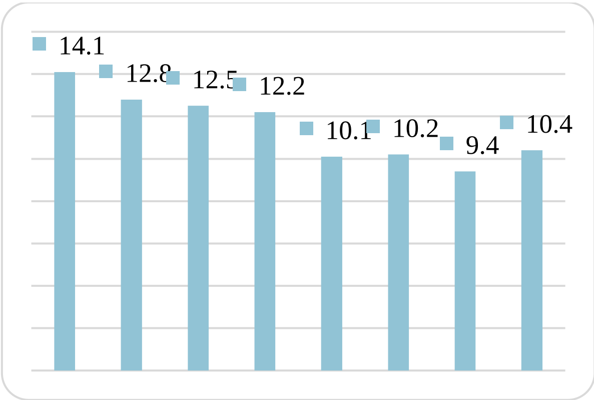


Fig. 2. Share of agriculture in GDP for the 2014-2021 years, %.
Source: National Bureau of Statistics [19, 20].

According to statistical data, the distribution of employed persons by economic activities shows that almost every fifth person works in the agricultural sector. A significant share of employment is in the agricultural sector, which in 2021 accounted for about 21% of the employed population (Fig. 3).

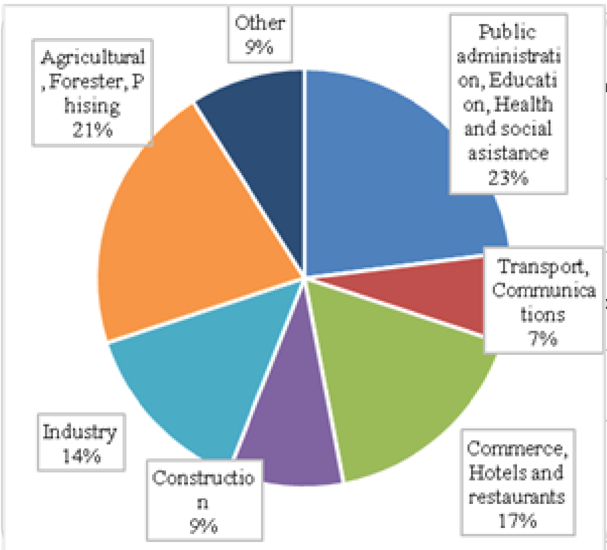


Fig. 3. Employment share by economic activity in 2021, %.
Source: National Bureau of Statistics [21].

In rural areas of the country, the employment rate is significant and accounts for 37%, but it may be higher, but it is not known due to the prevalence of informal employment.

A higher share of the sector in employment relative to GDP illustrates that productivity in the sector is lower than the rest of the economy and the role of the agricultural sector in the economy is slowly declining, but overall the role of the sector in the country is still large, especially in rural areas.

National competitiveness can be ensured by involving the export of high value added products which provide increased profits and respectively allow increasing wages. Also, emphasis should be placed not only on price but on quality parameters too, which would allow exported products to maintain retail market even under a strong national currency. Currency appreciation leads to higher prices of exports relative to imports. In these circumstances, the income received from exports can increase the volume of imports, including modern technologies, and thus having a positive effect on the trade balance, even with reduced exports [12].

The agri-food sector plays a key role for Moldovan exports. Over the years, the Republic of Moldova has signed a number of trade agreements facilitating cooperation opportunities with over 93 countries. The main trading partners for agri-food exports are Romania, Russia, Italy, Belarus, Switzerland, Poland, Turkey, Bulgaria and Germany.

In relation to European market most groups of products register advantages, a decreasing tendency is persistent after 2010. In 2016 disadvantages for beverages and animal or vegetable fats and oils are observed On the C.I.S. market, for all groups of agrifood products decreasing values and disadvantages are observed. Recent years high trade advantages for the groups of prepared foodstuffs, beverages and tobacco, animal and vegetable fats and oils is observed [5].

In recent years, agri-food exports have shown an increasing trend, demonstrated by the share of agri-food exports in total exports which was 45% in 2021, and in the first 6 months of 2022, this share increased even more, reaching 51% (Fig. 4).

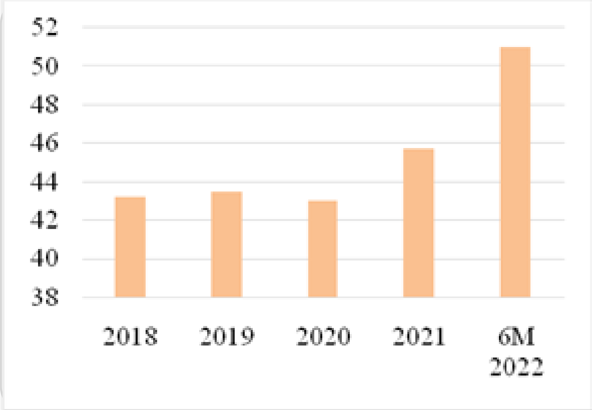


Fig. 4. Share of agri-food products in exports, %
Source: National Bureau of Statistics [22, 23].

The most export-oriented products are cereals and their derivatives, wine and spirits, oilseeds and oleaginous fruits, vegetable fats and oils, and fruits and vegetables, both fresh and processed - accounting for about 47% of the sector's total export volume (Figure 5). The European Union market remains the main destination for Moldovan exports, followed by the Commonwealth of Independent States - which together account for 82% of the country's foreign trade.

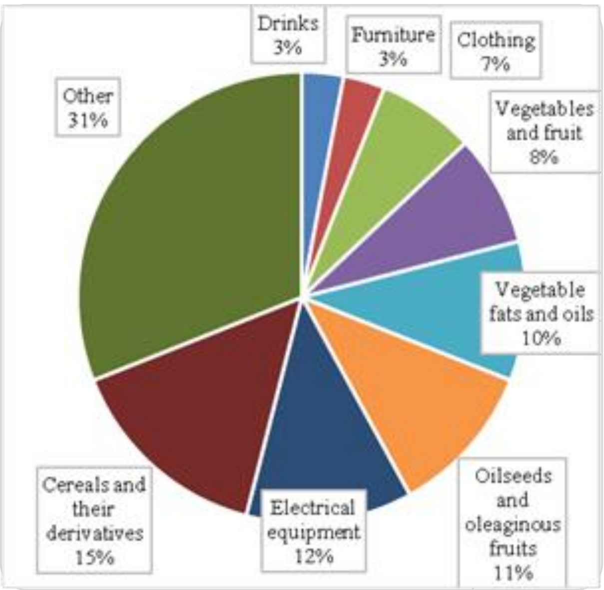


Fig. 5. Structure of exports by product categories from the Republic of Moldova, %.
Source: National Bureau of Statistics [22].

From those stated, we shall mention that trade has a strategic importance also for balanced and viable development of economic and social systems of any country. In the condition of market economy, in order to regulate the export - import relation, the necessity to achieve certain activities by the state is indisputable [7].

According to the international experts, international grain and vegetable oil prices have started to rise since mid-2021, but since the beginning of 2022, prices have risen even more, as both Ukraine and Russia are major exporters of grain (about 18% of world exports) and oilseeds/vegetable oils (e.g. sunflower oil, more than 50% of world exports) [16].

At the same time, at the beginning of the harvest season for cereals and oilseeds, prices have decreased insignificantly, but are still higher than before the beginning of 2022, especially for oilseeds and vegetable oils.

The increase in food prices is negatively affecting consumers in the Republic of Moldova, especially inflation, which has risen sharply, reaching 34.3% on 22 August (Fig. 6), one of the highest in the region and largely driven by food and energy prices [17, 18].

According to a recent World Bank study, Moldova is the country with the tenth highest food price inflation in the world.

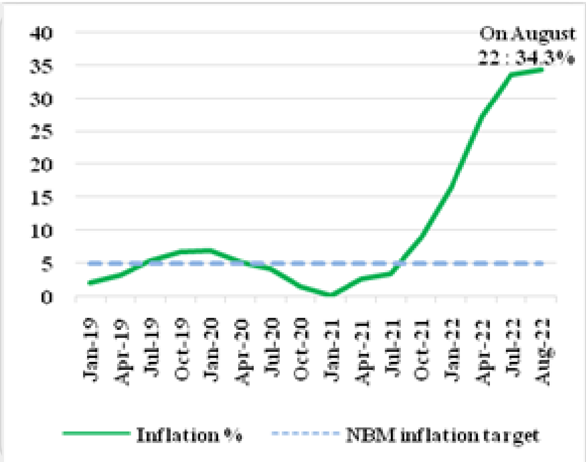


Fig. 6. Comparable inflation, January 2019-May 2022, %
Source: National Bank of Moldova [17, 18].

The situation in Moldova's agri-food sector would be positive if, as an exporter of cereals and oilseeds, it could benefit from higher prices for these commodities, but a visible impediment is the increase in prices of inputs, which have also risen, especially fertilizers (Fig. 7) and diesel (Fig. 8).

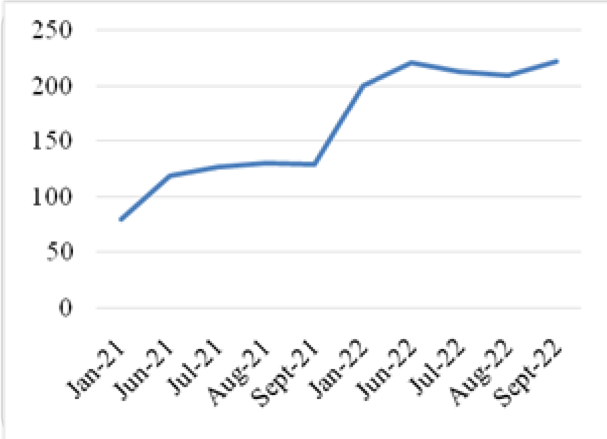


Fig. 7. International fertilizer prices, January 2021-September 2022, USD/t
Source: World Bank [38].

The maximum retail prices of the main standard petroleum products are set by National Energy Regulatory Agency on the basis of the Methodology for the calculation and application of petroleum product prices.

These inputs have a major impact on the cost structure of key agri-food production, where the share of fertilizer in total costs can be up to 50% for some crops, in addition, the strong increase in transport costs for exports from the Republic of Moldova, due to the congestion of logistics infrastructure due to Ukraine's inability to export through the Black Sea ports, thus using the road, rail and the Danube ports infrastructure of the country [30].

The agricultural policy in Moldova is aimed at enhancing the sustainable development of the agricultural sector and rural areas. Despite the fact that the government always supported the agricultural sector, most of these interventions were based on allocating financial support for certain programs aimed to support farmers, insurance risks, development of wine sector etc, often with the absence of a long term strategy. According to the agricultural support policy the allocated funds were directed towards three main priorities: increasing competitiveness of the agri-food sector through restructuration and modernization; insuring sustainable administration of natural resources; and increasing investments in infrastructure and services from rural areas [4].

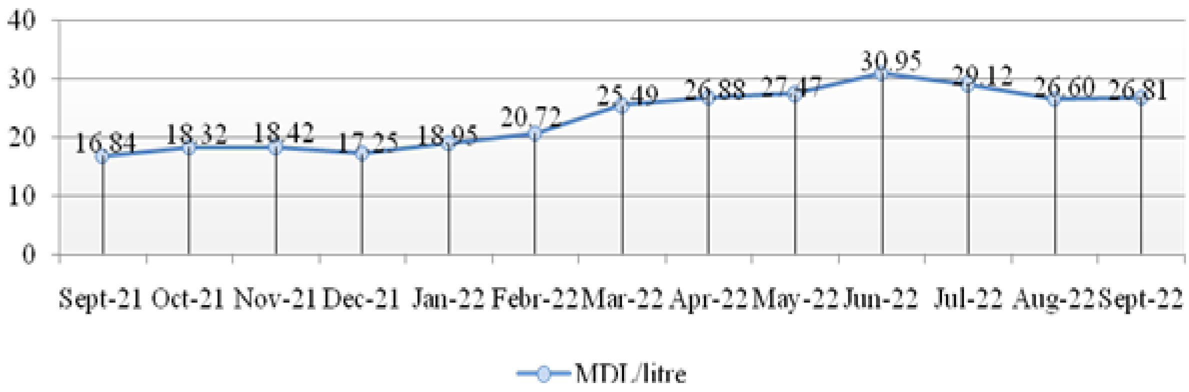


Fig. 8. Evolution of average diesel price, September 2021-September 2022, MDL/liter
Source: National Energy Regulatory Agency [27].

According to the programme of activity of the ruling party, in order to secure the income of the population and to increase public investment that ensures development of the economy, the Government has set itself the goal of restoring the confidence of development partners and unblocking external financing. Responsible policies are promoted by to ensure macro-economic stability and accelerate reforms First and foremost, the emphasis is on the state ensuring conditions of fair competition and universal respect for the law and the rules of the game, which is only possible after a genuine, structural reform of the judiciary and the supervisory bodies [32].
Secondly, efforts are being made to guide the country's economic system towards an efficient, investment-based economy.
Thirdly, the state needs to ensure legal and fiscal predictability that provides local entrepreneurs and foreign investors with economic and political stability.
These three preconditions are crucial for a functioning market economy and generate added value and innovation, i.e. economic progress and better living standards.
The vision of the current government is to lay the foundations for an economy that exists not only thanks to remittances, taxes and money coming from external partners, but one based on domestic production and increased labour productivity. An economy that generates sustainable and inclusive growth, that provides good jobs and for both those at home and those who have left but want to return [11].

## CONCLUSIONS

Agriculture in the Republic of Moldova is a sector of the economy that is as much in demand as it is sensitive. Intensive work is being done at institutional and business level to reduce the effects affecting the expansion of this sector. Bearing in mind that approximately one third of the population works in the agricultural sector, we conclude that agriculture is important for the socio-economic development of the country.
The first quarter of 2022 has been strongly shaken both economically and socially by the beginning of the hostilities in the region, which will affect the Republic of Moldova in the long term. Considering that Moldova is in close proximity to the conflict zone, the trade links with the affected states and the implications it has on import and export logistics has further amplified the negative impact of the international context on the country's agriculture and food security.
As a neighbouring country dependent on access routes with other states, namely through the territory of Ukraine, the hostilities in the region have a negative impact on external trade. The increase in the price of agri-food products has also taken place against the backdrop of high fuel and fertilizer prices, the drought of previous years, and transport logistics, which have been hampered by transit and transhipment capacity through the territory of the neighbouring state.
The response to the challenges would be to increase resilience which is becoming a

priority for state policies, namely the continued and consolidated development of agriculture and the food industry, with the realizing of the opportunities that have arisen being absolutely necessary.

The development of the agro-industrial sector and its increased adaptability to the situation created, provides first of all for the development of the infrastructure for production, post-harvesting and processing, which is in the early stages of development and has been influenced by the presence of cheaper raw materials from abroad, especially from Ukraine. The Republic of Moldova's ability to act on risks and the implementation of a well thought-out plan for the future can radically change the importance of the domestic agro-industrial sector not only in the domestic context but also internationally.

The current situation could provide impetus for improvements in the social security system, for example information technology solutions to better target and monitor support measures.

In order to redress the situation created, as recommended social policy measures, in the short term, to limit the negative impact on the population and to maintain as much as possible a better quality of life, it is proposed:

-to devise temporary support for producers to establish positive incentives, e.g. ex ante subsidies or tax exemptions to improve producers' planning possibilities;

-improving logistics infrastructure (road, rail and Danube ports), which could reduce some of the pressure on transport corridors (e.g. rail improvements, purchase of additional wagons), facilitating private investment in logistics infrastructure where possible;

-the cost of financing for farmers can be reduced with instruments such as credit guarantees or interest subsidies; for example, existing instruments could be temporarily extended.

However, it is important not to create dependency on support instruments, as they are only an incentive to avoid business stagnation.

In terms of long-term prospects for both government and business, it is recommended:

-improving and expanding irrigation infrastructure, which could reduce vulnerability to unpredictable natural phenomena;

-improving and developing post-harvest infrastructure (storage, processing), which can give domestic farmers more flexibility to react to changes in international prices and increase profit margins;

-focus on the development of higher value-added products, in order to move from raw material exports to processed exports;

-providing support for the transition to climate-resilient farming systems (including research, education and extension services).

Research has shown that the impact of the crisis caused by the hostilities in the region is a threat to the national economy and to the living standards of citizens, but that it strengthens both management, business and social forces through a decent assessment of the situation and proper planning, by drawing up good socio-economic policies and implementing them properly, it is possible to avoid increasing the level of poverty and, if not improving the quality of life, at least maintaining a decent standard of living. Let us not forget the words of the philosopher Francis Bacon, who told us that "It is not what we eat, but what we digest that makes us strong; it is not what we earn but what we save that makes us rich; it is not what we read but what we remember that makes us wise; it is not what we profess but what we practice that makes us upright".

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# GENETICALLY MODIFIED FOODS PERCEPTION OF CONSUMERS IN THE GLOBALIZING WORLD: A CASE STUDY FROM TURKEY

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***Abstract***

*The study was conducted by estimating logistic regression analysis to understand the factors affecting consumers' perception and purchasing intention of genetically modified (GM) foods in Isparta, Turkey. The information was gathered through face-to-face interviews with 264 consumers in the city of Isparta, Turkey. It was determined that being younger and having a higher education level positively affect the purchase intention of GM foods. Also, trust in health and safety is a sufficient factor to increase purchase intention even if there is distrust of the government. However, perceived risks do not significantly affect consumers' intentions to buy, and thus, benefit perception is more effective than risk perception. Consequently, the consumers' attitudes determine their purchase intentions for GM foods. This research has practical implications for food industry policymakers and producers, who might devise methods to enhance consumer expenditure on GM foods based on their excellent taste and favorable contribution to a healthy diet. This will be valuable for doing consumer-oriented evaluations and product development to understand better and predict consumer reactions and behavior.*

***Key words***: *consumer behavior, perception, purchase intention, genetically modified (GM) food, logistic regression, Turkey*

## INTRODUCTION

In many parts of the world, consumers are usually interested in safe, healthy, and unmodified foods [12]. Politicians, on the other hand, pursue agricultural policies using modern agricultural technology such as genetically modified organisms (GMOs), which are intended to advance product quality, yield, and disease resistance. Consumers generally tend to reject genetically modified (GM) foods, although there is a widespread agreement in scientific studies that GM foods are not more dangerous than conventional substitutes. This doubt is associated with mostly undiscovered long-term environmental and health outcomes [11].

The World Health Organization (WHO) defines GM foods as "foods derived from organisms whose genetic material (DNA) has been modified in a way that does not occur naturally" [46]. The genetics of living organisms has been modified using modern biotechnological methods since the 1970s [22]. Since the day it first appeared, the public and professionals have heavily discussed the advantages and disadvantages of GM foods. Its possible benefits include reducing agricultural costs, poverty, and starvation and increasing both farm productivity and the quality of food [51, 39]. In the health sector, it can be ensured that drugs and vaccines can be produced more cheaply and safely [18]. Also, water pollution can be prevented by reducing excessive fertilizer use by GM technology [47]. On the other hand, the potential risks are various allergic diseases, birth anomalies, and decreases in plant species [47, 35].

According to International Service for the Acquisition of Agri-biotech Applications ISAAA data [21], GM food production, which started at 1.7 million hectares in 1996, increased by 112-fold, and reached a total area of 190.4 million hectares worldwide in 2019. Biotechnology benefited approximately 1.95 billion people (26% of the world's population) and 17 million GM food farmers and their families. In 2019, the number of countries cultivating GM foods increased to 29, and the top countries with the broadest cultivated area are the USA (71.5 Mha), Brazil (52.8 Mha), Argentina (24 Mha), Canada (12.5 Mha), and India (11.9 Mha), respectively. Soybean is the foremost biotech crop with 91.9 Mha (48% of the world's GM crops) and is followed by maize (60.9 Mha), cotton (25.7 Mha), and canola (10.1 Mha). However, by diversifying these crops, it has become possible to offer more options to producers and consumers. Some of them are alfalfa (1.3 Mha), sugar beets (473,000 Ha), sugarcane (20,000 Ha), papaya (12,000 Ha), safflower (3,500 Ha), and potatoes (2,265 Ha), etc. [21]. Furthermore, between 1996 and 2016, an income of $186.1 billion was obtained from the production of GMO products worldwide. The USA ($80.3 billion), Argentina ($23.7 billion), India ($21.1 billion), Brazil ($19.8 billion), and China ($19.6 billion) received the lion's share of this income (Brookes & Barfoot, 2018, as quoted in [47]).

The regulations in Turkey regarding GM foods are quite firm. The Cartagena Protocol on Biosafety, which was approved by Turkey in 2003, has greatly influenced Turkey's national legislation.

The Cartagena Protocol on Biosafety is an international treaty (adopted on January 29th, 2000 and ratified by 180 countries) that deals with the possible adverse impacts of living modified organisms by considering the safe transportation, use and risks to human health [44].

According to Biosafety Law No. 5977, importing, exporting, and placing on the market require permission based on risk assessment using scientific principles. Also, these products must be labeled [30]. In 2018, the Biosafety Board allowed the import of GM products solely for animal feed, and the production of GM plants and animals was prohibited [41]. Although GM foods are not presently produced, since various products are obtained from GM-fed animals, these products reach consumers obliquely. For this reason, GM food producers and decision-makers need to understand better how they can focus on consumers' apprehensions, behaviors, and purchase intentions about GM foods. The literature on consumers' perception and purchase intention toward GM food is expanding. However, studies that systematically appraise and investigate consumer perception and purchase intention of GM foods are limited. Most of them only provide independent empirical evidence or theoretical clarification of the data. Also, there has been little research relating to Turkish consumers' perceptions and purchase intentions for GM food. At the same time, the fact that no similar research has been conducted in Isparta province highlights the importance of the study. For these purposes, the study aims to investigate econometrically the consumers' perceptions and the factors that may affect their purchase intentions of GM foods in Isparta province, Turkey. Therefore, the present research tries to investigate consumers' perceptions and purchase intentions and their influencing factors. This research is fundamental in ascertaining the purchase intentions, perceptions, and characteristics. Logistic regression analysis is employed to examine the impact of individual characteristics, consumers' perceptions of trust, benefit, risk, and attitude. Thus, this study aims to provide a reference for producers and policymakers.

The article is structured as follows: The next section the econometric model is presented, and the research method is discussed. Then, it is followed by the results and discussion sections.

**Literature review**

Different methods and theoretical models have been employed to analyze consumer behavior toward GM foods. There has been a lot of scientific interest in exploring the factors that affect consumers' acceptance [29, 10, 4, 13] and willingness to pay [11, 27, 5, 40] for GM foods considering the significance of predicting consumer attitudes and behavior. For instance, Kimenju and De Groote (2008) [23] estimated consumer awareness and the factors determining their willingness to pay for GM foods by surveying 604 participants in Nairobi, Kenya. They found that most of the participants, having limited knowledge of GM crops, were willing to pay for these crops at the same price as their favorite equivalent. However, they were worried about the potential adverse impact on the environment and biodiversity.

Bruschi, Teuber, and Dolgopolova (2015) [4] examined young Russians' acceptance and willingness to pay for novel functional food bakery products. The results showed that respondents had a low level of knowledge of anthocyanins, but they considered health-enhancing products more important than base products when information was provided. The respondents who did not have information on anthocyanin were willing to pay more for the purple wheat bakery products.

López et al. (2016) [25] calculated participants' perceptions and attitudes toward the production and consumption of GM foods in Mexico. A survey of 11 latent factors was conducted in the urban areas of Mexico to achieve this goal. Similar to previous studies, the results showed that the participants did not have enough knowledge of GM foods (31.28%). They were extremely insecure and perceived a high risk of GM foods (59.13%). Participants with a high level of education had a lower acceptance of GM foods. The authors also reported that they did not perceive positive health effects or social values of GMOs even if an increase occurred in agricultural productivity.

Zhang et al. (2018) [50] aimed to investigate Chinese consumers' purchase intention toward GM foods under the frameworks of benefit-risk analysis (BRA) and the theory of planned behavior (TPB) and to identify which framework affected the purchase intention. In this regard, the model was applied using the data obtained via an online survey with 408 participants. The analysis results explained that the consumers' positive attitude and trust in GM foods increased their purchase intention and perceived benefits under the BRA framework. On the other hand, trust decreased their perceived risks and indirectly purchased intentions. Under the TPB framework, attitude was the most important predictor of purchase intention. Furthermore, the BRA had a stronger impact in explaining the purchase intention compared to the TPB.

Regarding the studies focused on Turkey, Tas et al. (2015) [39] analyzed the consumers' awareness and perception of GM foods in Istanbul, Turkey. A nonparametric test was applied in the study to achieve this aim. The survey results presented that consumers generally had sufficient information about GMOs, but they were uninformed about the genetic modification process. Consumers were most concerned about the carcinogenic effect of GM foods on humans. The areas where GMO usage was most approved by consumers were the health sector and the prevention of environmental pollution. However, most consumers opposed its use in food applications.

Celik and Dagistan (2016) [6] investigated consumers' perceptions and purchase intentions of GM foods in the province of Hatay, Turkey. They analyzed data via Spearman Correlation Analysis. The risk perception level was considerably high for the participants and played a crucial role in determining the consumers' opinions and purchase intentions. Consumers preferred to purchase conventional foods over GM foods. Also, they had a low level of awareness and knowledge of GM foods. At the same time, their perceptions and attitudes were mostly based on prejudices.

The present research tries to investigate consumers' perceptions and purchase intentions and their influencing factors. This research is fundamental in ascertaining the purchase intentions, perceptions, and characteristics. Logistic regression analysis is employed to examine the impact of individual characteristics, consumers' perceptions of trust, benefit, risk, and attitude. Thus, this study aims to provide a reference for producers and policymakers.

## MATERIALS AND METHODS

### Questionnaire design

After the purpose of the study was determined, a large literature review was conducted, and similar studies to our subject were examined. Therefore, the questionnaire was developed in light of the information obtained from the literature.

The survey contains basic socio-economic information (individual characteristics) items as well as four other sections. These items include gender, age, marital status, education level, profession, monthly income, number of household members, whether there is a minor in the household, and primary household food buyer. The first of four other parts investigated whether consumers' trust in GM foods influences their intent to buy the products. The second part aimed to investigate the effects of the perceived benefit on the respondents' purchase intention for GM foods. In the third part, the perceived risk was questioned to identify respondents' purchase intention for GM foods. The final part of the survey asked if attitude influences consumers' purchase intention toward GM foods (see Table 1 for more details).

**Likert-type scale**

Trust, perceived benefits, perceived risk, and attitudes, except for individual characteristics of the respondents, were measured using appropriate labels on a Likert-type scale. In the social sciences, the Likert-type scale is the most commonly used research method for surveying attitudes. Respondents are asked to indicate how much they agree with a declarative statement. Each scale point in a five-point method could be labeled by its agreement level as follows: Definitely yes, yes, no opinion, no, definitely no. The scale labels could be expressed differently depending on what is being measured [49]. The Cronbach's Alpha and Principal Component Analysis were used to assess the reliability and validity, respectively.

**Sampling methods**

The necessary data were obtained from the surveys conducted by face-to-face interviews with 264 consumers in the urban part of Isparta from January to February 2020. The sample population was selected by a single-stage, non-clustered, simple random probability sampling method based on main mass ratios [9].

$$n=(z^2*p*(1-p))/d^2 \qquad (1)$$

where, n=required sample size, z=confidence level at 95% (standard value of 1.96), p=expected proportion of the event in the study area, and d=precision or margin of error at 5% (standard value of 0.05).

First of all, according to the results of the 2020 census, the population of the city center (262,255) was determined to calculate the sample size of the research. To determine the prevalence value in the formula, 80 preliminary surveys were conducted in the city center of Isparta. According to the preliminary survey findings, it was found that 80% of the families in the research area consumed GM foods. Thus, a sample size of 264 was calculated using Equation (1). After determining the required sample size, the total neighborhoods in the city center of Isparta were divided into three groups according to their socio-economic characteristics: low, middle, and high income. Then, a survey was conducted in 15 neighborhoods that could represent the research area. The number of surveys to be conducted in each neighborhood was distributed in proportion to the population of the neihborhoods, and consumers were chosen randomly.

**Econometric modeling methods**

A logistic regression model was used to analyze consumers' perceptions and the factors affecting their purchase behavior. In the model, the dependent variable is consumers' purchase intention toward GM foods, and the affecting factors are classified into five categories. These are individual characteristics, trust, perceived benefit, perceived risk, and attitude toward buying. Each category was developed in light of the information obtained from the literature review. The variables applied in the analyses under these five categories and their definitions are provided in Table 1. Furthermore, the model was developed and empirically tested using the defined data in the research via SPSS software (IBM Corp., Version 26.0, Armonk, NY, USA) [38].

The model is a nonlinear regression model conceived especially for the dichotomous dependent variable. A logistic binary choice model was employed to estimate the impact of those factors on consumers' intention to purchase GM foods. The model assumed that y=1 if the consumer intends to purchase GM foods and y=0 otherwise. Thus, the econometric model based on the logistic probability function is as follows [17]:

$$Prob(Y_i=1)=P_i=F(Z_i)=F(\alpha+\beta X_i) \quad (2)$$
$$=1/(1+e^{\wedge}(-(Z_i))$$
$$=1/(1+e^{\wedge}(-(\alpha+\beta X_i)))$$
$$Prob(Y_i=0)=1-P_i=1/(1+e^{\wedge}(\alpha+\beta X_i)) \quad (3)$$

where: F is the cumulative probability function, e is the exponential constant, α is the constant coefficient, β is the parameter to estimate for each explanatory variable, and $X_i$ refers to the ith independent variable.
From equations (2) and (3),

$$Prob(Y_i=1)/Prob(Y_i=0) =P_i/(1-P_i)=e^{\wedge}(Z_i) \quad (4)$$

The following equation is obtained by taking the natural logarithm of both sides of the equation (4).

$$L_i=\ln[Pi/(1-P_i)]=Z_i=\alpha+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n+\varepsilon_i \quad (5)$$

Logistic is an advantageous regression model because binary logistic models do not rely on the assumption of linearity between dependent and independent variables and do not assume homoscedasticity.

## RESULTS AND DISCUSSIONS

### Descriptive statistics

The sample size consists of 264 observations which are 132 females and 132 males. When the educational status is examined, nearly half of the respondents (48.86%) have a high educational level (i.e. undergraduate and over). It is also observed that 50.8% of them are married. There is a significant variation in the respondents' income level from 1,500 TL ≤ to 10,500 TL ≥. Approximately half of the participants (47%) indicate being in the monthly income group of 4,501 – 7,500 TL, and 20.8% of them is in the 1,501 – 4,500 TL group. Regarding profession which depends on an International Labour Organization (ILO) and its International Standard Classification of Occupations (ISCO) [20], most of the consumers are professionals (21.6%) and students (18.9%). Concerning the number of household members, 58% of them have at least four persons in the family. Furthermore, 28.4% of the respondents are the primary household food buyer and the proportion of households with minors is 57.2%. Descriptive analysis of the variables is given in Table 2 in detail.

### Estimated results

As mentioned earlier, the logistic regression model was employed to determine the consumers' perceptions and the factors affecting their purchase intention for GM foods in Isparta province, Turkey. Following the data processing, the results of the estimated logistic regression model are presented in Table 3. The goodness of fit measurements shows that the model fits the data reasonably well. The Nagelkerke $R^2$ is 0.56, and the 2 log-likelihood value, which measures the significance of the logit function, is 91.686. The chi-square value is 82.580 (P=0.004), and the Hosmer-Lemeshow test result is 21.973 (0.005). It means that the independent variables have good explanatory power for the dependent variables. It should also be noted that Logistic regression coefficients do not reflect the magnitude of the change. However, it only reflects the direction.
For every five factors, the results of the consumers' purchase intention towards GM foods and the affecting factors in Isparta province, Turkey are presented below.

***Individual characteristics***

Firstly, we hypothesized that consumers' perception and purchase intention for GM foods primarily depend on their individual and family characteristics. The characteristics examined in this category in the study are gender, age, marital status, education, profession, monthly income, number of household members, whether there is a minor in the household, and primary household food buyer.
As explained by the results in Table 3, some of the individual characteristics are significant at the level of 1%. These are marital status (A3, married), and whether the family has a minor (A8). The education level (A4) and the number of family members (A7) are statistically significant at the 5% level.
On the other hand, gender (A1), age (A2), profession (A5), monthly income (A6), and primary household food buyer (A9) turn out

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to be insignificant although most of the signs are as expected.

Table 1. Definition of variables

| Variable name | Definition |
|---|---|
| **A** | **Individual Characteristics** |
| A1 | Gender |
| A2 | Age |
| A3 | Marital Status |
| A4 | Education |
| A5 | Profession |
| A6 | Monthly Income |
| A7 | Number of family members |
| A8 | The family has a minor |
| A9 | Primary household food buyer |
| **B** | **Trust** |
| B1 | Do you think GM foods will improve the quality of human life? |
| B2 | Do you have confidence in the effective implementation of the biosafety law in Turkey? |
| B3 | Do you have confidence that GM foods are properly labelled or that the ingredients of the products are sufficiently accurate and clear? |
| B4 | Do you have confidence that there is sufficient control of GM foods in Turkey? |
| B5 | Do you have confidence in food products obtained from animals consuming GMO feed are healthy? |
| **C** | **Perceived Benefit** |
| C1 | Do you think individuals should consume genetically modified products at an early age? |
| C2 | Do you think that GM foods are beneficial for human health? |
| C3 | Do you think that foods will become better quality thanks to genetically modified organisms? |
| C4 | Do you think genetically modified organisms cause increases in food production? |
| C5 | Do you think that products resistant to some agricultural diseases have been obtained thanks to genetically modified organisms? |
| C6 | Do you think that GM products are rich in nutritional structures? |
| C7 | Do you think that GMO is fighting hunger in the world? |
| C8 | Do you think the storage and shelf life of GM foods become longer? |
| **D** | **Perceived Risk** |
| D1 | Do you think that GM plants harm living things in the soil? |
| D2 | Do you think that GM animal feeds negatively affect the health of animals and cause organ problems? |
| D3 | Do you think GM foods are not nutritious enough? |
| D4 | Do you think that GM foods have harmful side effects such as toxic, allergic, teratogenic (structural anomalies seen in the unborn baby)? |
| D5 | Do you think GMO cause the loss of biodiversity in plants? |
| **E** | **Attitude towards buying** |
| E1 | Would you buy GM fruits and vegetables with an extended shelf life? |
| E2 | Would you buy herbal products made resistant to pests to reducing the use of pesticides? |
| E3 | Would you buy GM foods if the quality of GM foods is better than the quality of non-GM foods? |
| E4 | Would you buy GM foods if GM foods are cheaper than non-GM foods? |
| E5 | Would you buy non-GM products from an unrecognized brand if the brand of GM foods is a well-known and reliable brand? |
| E6 | Would you buy GM products if the GM foods are better in terms of nutritional properties than the non-GM foods? |
| E7 | Would you buy GM foods if GM foods are better in terms of colour, taste, aroma and size than non-GM foods? |
| E8 | Would you buy chickens that have been gene transferred from a different animal species to have less fat? |
| E9 | Would you buy foods such as carp, catfish, salmon, and tilefish that are made resistant to cold conditions with gene transfer? |

Source: Authors' calculation based on survey data.

The younger generation is more interested in technological and scientific developments and is more inclined to accept GM technology accordingly. Therefore, they are expected to positively affect the purchase intention of GM foods. According to regression results, increasing age has a negative effect as predicted. The results also reveal that being married negatively affects the purchase intention of GM foods. The coefficient estimate on whether there is a minor in the household is negative and statistically significant. Similarly, Delmond et al. (2018) [11] showed the negative impact of having a child in the household on Russian consumers' willingness to pay for GM foods in their research. Furthermore, consumers with high levels of education are anticipated to have a high awareness of GMOs. The coefficient estimate on education levels is positive according to our results—the intention to buy GMOs increases when the education level increases. Participants with a higher education are nearly five times more likely to purchase GM foods than the reference group of participants with a low education level. This beneficial effect of education on purchase intention was supported by Loureiro and Hine (2004) [26] and Tas et al. (2015) [39]. In Mehmetoglu's (2007) [28] study, which used a sample of the population of Turkey, found that young people with higher levels of education or income were more aware of GM foods than older consumers with lower levels of education or income. Moreover, the coefficient of the number of family members is negative, and it implies that the intention to purchase GM foods decreases as the number of households increases. This result is consistent with the education and income variables because crowded families generally have low income and education levels in Turkey.

On the other hand, gender and the primary household food buyer do not have a statistically significant effect on purchasing GM foods. Interestingly, monthly income is also statistically insignificant. However, the estimated coefficient of monthly income carries a positive sign as predicted. The positive sign shows that participants with higher income levels are more likely to purchase GM foods. It may be said that a low level of education is positively related to a low level of income, although the monthly income is statistically insignificant.

*Trust*

Trust is an essential variable in accepting GM foods. However, scientific researchers are not able to agree on this issue. Some empirical studies have suggested that trust does not directly affect the consumer's intention toward GM foods [7, 32]; others [19, 42, 3, 37, 24] have shown that trust is a critical determinant of adoption of GM foods.

Therefore, we aimed to see how the participants' confidence in GM foods affects their intention to purchase the products. For this purpose, five questions (B section in Table 1) were asked of the respondents, and only the expression B4 was found statistically significant at the 5% level. In Question B4, it was asked whether they have confidence that there is sufficient control of GM foods in Turkey. According to this result, it is observed that the participants who trust that the GM foods are adequately controlled intend to purchase GM foods 3.12 times less compared to the participants who do not trust, contrary to our expectation. When looking at other explanatory variables examining the trust, it is seen that they are statistically insignificant. Regarding the signs of the coefficients, respondents who stated GM foods are safe for human health and improve quality of life intend to purchase GM foods more. However, those who trust in government policy implementations related to GM foods intend to buy less. In line with the results obtained, this situation can be explained as follows. It is thought that the higher the education level, the less confidence in the government's practices. At the same time, it is a fact that individuals with a high level of education also follow scientific developments more. Thus, trust in the health and safety of GM foods may be a sufficient factor to increase the purchase intention even if there is distrust in the government. According to Kaya et al. (2013) [22], in their study of Turkey in general, it was seen that the sense of trust in the

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institution related to the control of GM foods was at a very low level (8.9%).

*Perceived benefit*

Several previous studies have posited that perceived benefits are significantly correlated with purchase intention [19, 14, 7, 10, 33]. Therefore, eight questions were asked about the perceived benefit to identify the affecting factors of respondents' purchase intention for GM foods, such as the benefits to human and animal health, positive effects on agriculture, and hunger problems. Only C1 was statistically significant.

The variable C1 was found to be statistically significant at a 5% level. According to the results, the respondents who think that GM products should not be consumed at an early age tend to buy 4.81 times more GM foods. This situation shows that individuals think GM foods may be harmful to children instead of themselves. It is also a sign that individuals are trying to be more careful and attentive to their children's health. Similarly, Kaya et al. (2013) [22] stated that the rate of those who think that consuming GM products is inconvenient for children was quite high for the sample of the Turkish population.

Although other variables employed in examining the perceived benefit are not statistically significant, their signs of the coefficients are mostly as a priori predicted. The participants, who think GM foods are beneficial for human health, tend to purchase 1.8 times more than those who do not think so. In C3, participants who think that foods will become better quality thanks to GMOs intend to purchase 0.39 times fewer GM foods. For variable C5, the participants were asked the question, "Do you think that products resistant to some agricultural diseases have been obtained thanks to GMOs?". Thus, it was determined that the participants who said yes to this question intended to buy 2.27 times more GM foods. For variable C4, respondents who think that GMOs cause increases in food production are inclined to buy 1.2 times less. Also, the opinion that GM products are rich in nutritional structures and fight hunger does not have a positive effect on consumers' intention to buy GM foods. This finding is in line with that of Canavari and Nayga (2009) [5] and Bawa and Anilakumar (2013) [2]. Finally, participants who think the storage and shelf life of GM foods become longer have an intention to purchase 1.14 times more. This result shows us that benefits such as storage and long shelf life are easily perceived by individuals. This favorable effect is supported by [1].

In a nutshell, the results cannot provide strong evidence for the presence of perceived benefits in GM foods purchase intention. However, it is seen that benefits such as finding foods beneficial for human health, obtaining products resistant to agricultural diseases, and increasing the storage and shelf life of foods lead the consumer to buy GM foods.

*Perceived risk*

Studies such as Grunert et al. (2001) [16], Rousu et al. (2004) [34], Chen (2008) [8], and Zhang et al. (2018) [50] have shown that GM foods are refused when the risks perceived by consumers are greater than the risks associated with traditional foods. According to Veeman and Adamowicz (2004) [45], large numbers of consumers perceive a greater risk associated with transgenic food due to the ambiguity of possibly hidden impacts generated by these products. Based on these findings, five questions about the perceived risk that may determine the affecting factors of respondents' purchase intention for GM foods were analyzed in the research.

According to the results, the variables D1 and D5 were statistically significant at the 5% level. The result of the D5 variable in this section shows that the participants who do not think that GMOs cause a loss of biodiversity in plants are 4.1 times more likely to buy GM foods. However, individuals who think that GM plants harm living things in the soil are more likely to purchase GM foods. Similarly, the participants who believe that GM foods have harmful side effects such as toxic, allergic, and teratogenic (structural anomalies in the unborn baby) have more intention to buy.

Table 2. Descriptive analysis of the variables

| Variable name | Number/percentage |
|---|---|
| **A** | **Individual Characteristics** |
| A1 | Male 132/50%, Female 132/50% |
| A2 | 18-25 74/28%, 26-33 76/28.8%, 34-41 61/23.1%, 42-49 61/23.1%, 50 ≥ 32/12.1% |
| A3 | Single 105/39.8%, Married 134/50.8%, Divorced 25/9.5% |
| A4 | Primary School 2/0.8%, Secondary School 13/4.9%, High School 120/45.5%, Associate Degree 56/21.2%, Bachelor's Degree 68/25.8%, Master's Degree 4/1.5%, Doctorate (PhD)1/0.4% |
| A5 | Managers 7/2.7%, Professionals 57/21.6%, Technicians and Associate Professionals 21/8%, Clerical Support Workers 3/1.1%, Services and Sales Workers 30/11.4%, Craft and Related Trades Workers 12/4.5%, Plant and Machine Operators, and Assemblers 2/0.8%, Elementary Occupations 17/6.4%, Retired 31/11.7%, Unemployed 34/12.9%, Student 50/18.9% |
| A6 | 1,500 TL ≤ 12/4.5%, 1,501 – 4,500 TL 55/20.8%, 4,501 – 7,500 TL 124/47%, 7,501– 10,499 TL 53/20.1%, 10,500 TL ≥ 20/7.6% |
| A7 | 1 person 3/1,1%, 2 persons 25/9.5%, 3 persons 83/31.4%, 4 persons 90/34.1%, 5 persons ≥ 63/23.9% |
| A8 | Yes 151/57.2%, No 113/42.8% |
| A9 | Myself 75/28.4%, Mother and father 55/20.8%, Partner 37/14%, My partner and I 64/24.2%, Whole family 33/12.5% |
| **B** | **Trust** |
| B1 | Definitely yes 7/2.7%, Yes 9/3.4%, No opinion 44/16.7%, No 108/40.9%, Definitely no 96/36.4% |
| B2 | Yes 68/25.8%, No opinion 58/22%, No 138/52.3% |
| B3 | Definitely yes 11/4.2%, Yes 52/19.7%, No opinion 59/22.3%, No 90/34.1%, Definitely no 52/19.7% |
| B4 | Definitely yes 12/4.5%, Yes 44/16.7%, No opinion 74/28%, No 90/34.1%, Definitely no 44/16.7% |
| B5 | Definitely yes 0/0%, Yes 0/0%, No opinion 53/20.1%, No 119/45.1%, Definitely no 92/34.8% |
| **C** | **Perceived Benefit** |
| C1 | Definitely yes 0/0%, Yes 0/0%, No opinion 22/8.3%, No 97/36.7%, Definitely no145/54.9% |
| C2 | Definitely yes 0/0%, Yes 2/0.8%, No opinion 47/17.8%, No 98/37.1%, Definitely no 117/44.3% |
| C3 | Definitely yes 0/0%, Yes 1/0.4%, No opinion 90/34.1%, No 106/40.2%, Definitely no 67/25.4% |
| C4 | Definitely yes 1/0.4%, Yes 38/14.4%, No opinion 104/39.4%, No 75/28.4%, Definitely no 46/17.4% |
| C5 | Definitely yes 2/0.8%, Yes 37/14%, No opinion 107/40.5%, No 75/28.4%, Definitely no 43/16.3% |
| C6 | Definitely yes 2/0.8%, Yes 16/6.1%, No opinion 68/25.8%, No 106/40.2%, Definitely no 72/27.3% |
| C7 | Definitely yes 0/0%, Yes 15/5.7%, No opinion 91/34.5%, No 107/40.5%, Definitely no 51/19.3% |
| C8 | Definitely yes 7/2.7%, Yes 75/28.4%, No opinion 92/34.8%, No 61/23.1%, Definitely no 29/11% |
| **D** | **Perceived Risk** |
| D1 | Definitely yes 102/38.6%, Yes 126/47.7%, No opinion 36/13.6%, No 0/0%, Definitely no 0/0% |
| D2 | Definitely yes 90/34.1%, Yes 132/50%, No opinion 40/15.2, No 2/0.2%, Definitely no 0/0% |
| D3 | Definitely yes 113/42.8%, Yes 106/40.2%, No opinion 45/17%, No 0/0%, Definitely no 0/0% |
| D4 | Definitely yes 115/43.6%, Yes 105/39.8%, No opinion 44/16.7%, No 0/0%, Definitely no 0/0% |
| D5 | Definitely yes 95/36%, Yes 107/40.5, No opinion 62/23.5%, No 0/0%, Definitely no 0/0% |
| **E** | **Attitude towards buying** |
| E1 | Definitely yes 0/0%, Yes 4/1.5%, No opinion 44/16.7%, No 110/41.7, Definitely no 106/40.2% |
| E2 | Definitely yes 0/0%, Yes 2/0.8%, No opinion 56/21.2%, No 112/42.4%, Definitely no 94/35.6% |
| E3 | Definitely yes 0/0%, Yes 8/3%, No opinion 45/27%, No 121/45.8%, Definitely no 90/34.1% |
| E4 | Definitely yes 0/0%, Yes 6/2.3%, No opinion 68/25.8%, No 103/39, Definitely no 87/33% |
| E5 | Definitely yes 24/9.1%, Yes90/34.1%, No opinion 101/38.3%, No 27/10.2%, Definitely no 22/8.3% |
| E6 | Definitely yes 0/0%, Yes 7/2.7%, No opinion 75/28.4%, No 107/40.5%, Definitely no 75/28.4 |
| E7 | Definitely yes 0/0%, Yes 6/2.3%, No opinion 58/22%, No 101/38.3%, Definitely no 99/37.5% |
| E8 | Definitely yes 0/0%, Yes 1/0.4%, No opinion 42/15.9%, No 103/39%, Definitely no 118/44.7% |
| E9 | Definitely yes 0/0%, Yes 1/0.4%, No opinion 39/14.8%, No 113/42.8%, Definitely no 111/42% |

Source: Authors' calculation based on survey data.

Table 3. Logistic regression results

| Factors | $\beta$ | Wald | Sig | Exp($\beta$) |
|---|---|---|---|---|
| A1 | -.975 | 1.446 | .229 | .377 |
| A2 | -1.232 | 3.397 | .065 | .292 |
| A3 | | 11.529 | .003*** | |
| Single | 1.041 | .240 | .624 | 2.832 |
| Married | -4.407 | 8.066 | .005*** | .012 |
| A4 | 1.578 | 6.274 | .012** | 4.846 |
| A5 | | 9.702 | .467 | |
| Managers | -21.929 | .000 | .998 | .000 |
| Professionals | -2.690 | 2.862 | .091 | .068 |
| Technicians and Associate Professionals | -3.590 | 2.994 | .084 | .028 |
| Clerical Support Workers | -.494 | .051 | .822 | .610 |
| Services and Sales Workers | -2.198 | 1.601 | .206 | .111 |
| Craft and Related Trades Workers | -2.156 | .674 | .412 | .116 |
| Plant and Machine Operators, and Assemblers | -17.774 | .000 | .999 | .000 |
| Elementary Occupations | -3.680 | 2.303 | .129 | .025 |
| Retired | 2.388 | 1.041 | .308 | 10.888 |
| Unemployed | -.793 | .340 | .560 | .453 |
| A6 | .084 | .039 | .843 | 1.087 |
| A7 | -1.076 | 5.184 | .023** | .341 |
| A8 | -6.524 | 8.614 | .003*** | .001 |
| A9 | | 3.462 | .484 | |
| Mother and father | -2.250 | 3.286 | .070 | .105 |
| Partner | -.631 | .263 | .608 | .532 |
| My partner and I | -2.192 | 1.172 | .279 | .112 |
| Whole family | -1.012 | .525 | .469 | .364 |
| B1 | -.026 | .005 | .944 | .974 |
| B2 | .069 | .013 | .908 | 1.071 |
| B3 | -.475 | 1.152 | .283 | .622 |
| B4 | 1.142 | 5.960 | .015** | 3.133 |
| B5 | -.075 | .025 | .876 | .928 |
| C1 | 1.570 | 4.379 | .036** | 4.806 |
| C2 | -.589 | 1.326 | .249 | .555 |
| C3 | -.933 | 2.803 | .094 | .393 |
| C4 | .145 | .083 | .773 | 1.156 |
| C5 | .819 | 2.798 | .094 | 2.269 |
| C6 | .386 | .840 | .359 | 1.472 |
| C7 | .743 | 2.348 | .125 | 2.103 |
| C8 | -.136 | .120 | .729 | .873 |
| D1 | -1.466 | 5.080 | .024** | .231 |
| D2 | .256 | .186 | .666 | 1.292 |
| D3 | -.004 | .000 | .995 | .996 |
| D4 | -.952 | 3.336 | .068 | .386 |
| D5 | 1.410 | 5.846 | .016** | 4.098 |
| E1 | .121 | .057 | .811 | 1.128 |
| E2 | .258 | .244 | .621 | 1.294 |
| E3 | -.140 | .104 | .747 | .869 |
| E4 | -1.359 | 5.154 | .023** | .257 |
| E5 | -.455 | 1.205 | .272 | .635 |
| E6 | 1.132 | 5.737 | .017** | 3.103 |
| E7 | -.655 | 2.006 | .157 | .519 |
| E8 | .633 | 1.615 | .204 | 1.883 |
| E9 | -2.422 | 11.936 | .001*** | .089 |

Chi-square: 81.048 (0.004)
Log likelihood: 93.217, Nagelkerke R Square: 0.547
Hosmer and Lemeshow Test: 26.451 (0.001)

Note: Statistically significant at the level of $p < 0.01$ (***), and $p < 0.05$ (**), respectively.
Source: Authors' calculation based on survey data.

On the other hand, the respondents, who do not think that GM animal feeds negatively affect the health of animals and/or cause organ problems, intend to buy GM foods 1.29 times more. Although this variable is not statistically significant, its sign is as expected. Furthermore, those who think GM foods are not nutritious enough tend to buy more.

In line with the results obtained, perceived risks do not have a considerable effect on

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purchase intention for GM foods. Hence, the perceived risks do not significantly affect consumers' purchase intention for GM foods even if they perceive their possible risks. According to the findings, perceived risks have no significant effect on purchase intention for GM foods. In a study conducted throughout Turkey by Oguz (2009) [31], it was determined that the perceived risk of GMOs for consumers and environmental safety increased with the improvement in education level. However, it was concluded that they believed that these effects could be partially brought under control by government control. Therefore, it can be stated that benefit perception is more effective than risk perception in our case. This result is supported by several studies [36, 43, 15] on the perception and purchase intention of GM foods.

*Attitude toward buying*

Kraus's 1995 study (as quoted in Zhang et al., 2018 [50]) defined "attitude" as a significant psychological structure influencing and predicting consumer behavior. According to some studies [33, 15, 50], attitudes toward GM food and its technology are significant determinants of whether people purchase GM foods. In this regard, the attitude was examined to explain whether it influences consumers' purchase intention toward GM foods. For this aim, all participants in the research were asked a range of questions about their attitudes toward buying these foods. From the results of the logistic regression model in Table 3, it was seen that the three variables (E4, E6, and E9) reached a significance level of 5%.

In E4, the respondents who state that they will buy GM foods if they are cheaper than non-GM foods have more intention of buying GM foods, as expected. Our result is consistent with that of López et al. (2016) [25], which obtained the result that consumers preferred cheaper products. In contrast, Yang, Ames, and Berning (2015) [48] argued that Taiwanese consumers tended to buy non-GM foods even if they were more expensive. Regarding E9, participants who display a less positive attitude towards foods such as carp, catfish, salmon, and tilefish that are made resistant to cold conditions by gene transfer have less purchasing intention, as hypothesized. However, another statistically significant variable, E6, shows that the respondents who express they will not buy GM foods even if they are better in terms of nutritional properties than non-GM foods, tend to buy the GM foods 3.1 times more. Similarly, although consumers who declare their refusal to buy GM fruits and vegetables with an extended shelf life and transgenic chickens (from different animal species) with less fat, they finally tend to buy more GM foods. The result is also propounded in López et al. (2016) [25].

Nevertheless, participants' tendency to purchase GM foods is consistent with their answers for variables E3, E5, and E7. Respondents who say that they will buy GM foods if their quality is better than the quality of non-GM foods are willing to pay 0.87 times more. Furthermore, respondents who state that they will buy GM foods from a well-known and reliable brand instead of non-GM foods from an unrecognized brand have the intention of buying GM foods 1.57 times more. Finally, it can be seen from the results that people will prefer to buy GM foods if they are better than non-GM foods in terms of color, taste, aroma, and size. Overall, the results indicate that consumers' attitudes toward buying GM foods affect their purchase intention.

## CONCLUSIONS

GM products are a difficult and important topic due to their controversial nature. Therefore, attitudes and behavior toward GM foods have been theoretically investigated from several different perspectives. As far as it is known, it has not been handled that an issue of consumers' perception and purchase intention for GM foods in Isparta, Turkey. Therefore, the paper explores econometrically the consumers' perception and the factors affecting the purchase intention of GM foods in Isparta province, Turkey. Following this purpose, the Logistic regression model is estimated with the primary data on demographic and cognitive factors collected through a survey. These factors are individual characteristics, trust, perceived benefit, perceived risk, and attitude to buying. The survey was conducted with 264 consumers located in the city center of Isparta, Turkey.

Empirical results indicate that consumers' perception and intention of purchasing GM foods are driven by demographic and cognitive characteristics. In terms of demographic characteristics, decreasing age positively affects the purchase intention of GM foods, while being married has a negative effect on it. Similarly, having a minor in the household also has a negative effect. On the other hand, consumers with higher education have nearly five times more intention to purchase GM foods. Furthermore, it is seen from the results that the intention to purchase GM foods decreases as the number of households increases.

Regarding cognitive characteristics, the results show that trust does not directly affect the consumer's intention toward GM foods. However, in line with the results obtained, it is observed that trust in the health and safety of GM foods may be a sufficient factor to increase purchase intention even if there is distrust of the government.

The research also established that the perception of risk and benefit does not provide strong evidence of purchasing intention toward GM foods. According to the results, those who think that GM foods are beneficial for human health and the storage and shelf life of GM foods have become longer intend to buy more GM foods. Also, consumers who think that products resistant to some agricultural diseases have been obtained thanks to GMOs intend to buy more GM foods. The participants who think that GMOs cause a loss of biodiversity in plants are less likely to buy GM foods. At the same time, the respondents, who think that GM animal feeds negatively affect the health of animals, intend to buy fewer GM foods. However, it is found that individuals who think GM plants harm living things in the soil and that GM foods have harmful side effects such as being toxic, allergic, or teratogenic are more likely to purchase GM foods. As a result, it is revealed that perceived risk does not significantly affect consumers' intention to buy GM foods, even if consumers perceive their potential risks. Hence, it can be said that benefit perception is more effective than risk perception.

Furthermore, the empirical outcomes confirm the critical role of attitude on consumers' intention to purchase GM foods. When we look at its effect on purchasing, consumer attitudes appear to positively affect purchasing intentions if GM foods are cheaper, of better quality, from a well-known and reliable brand, and of better color, taste, aroma, and size than non-GM foods. Furthermore, the participants, who display a less positive attitude toward foods such as carp, catfish, salmon, and tilefish that are made resistant to cold conditions by gene transfer, have less purchasing intention. As a result of the analyses, in general, the findings show that the attitudes of consumers toward purchasing GM foods determine their purchase intentions.

In light of the regression results, some changes may positively contribute to the production and consumption levels of GM foods. To achieve this purpose, it is necessary to raise the consumers' awareness about how healthy GM foods are. In other words, there is a need for comprehensive education using accurate and well-regulated informative materials. Following that aim, the information should be provided via the internet and public media sources such as TVs and radios. These sources are quite important due to their ability to inform directly and serve as primary sources for consumers. Hard and soft-copy materials such as brochures, social media posts, and public service announcements should also be provided. Grasping GMOs thoroughly will help to trust them and to better understand the level of risk and benefit perceptions. It is difficult and time-consuming to build confidence in emerging countries like Turkey. Therefore, policymakers could try to increase consumers' trust in these foods by strengthening relationships among consumers, producers, and the government. From this viewpoint, the research can lead to developing new guidelines and policies to produce and trade more comprehensively. Furthermore, it provides an extensive foundation that can create awareness, support consumers in areas where they feel lacking, and guide food producers and local authorities on practical implications.

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# ECONOMIC ASSESSMENT OF TILLAGE PRACTICES ON PRODUCTIVITY OF COWPEA IN ILE IFE, NIGERIA

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***Abstract***

*Tillage is one of the major threats to soil health which often results into soil physical degradation if not properly manage. Zero tillage was an alternative option from both economic point of view and environmental protection of our invaluable soil resources. The goal of the present scientific paper is to evaluate the response of different tillage systems and evapotranspiration on productivity of cowpea (Vignaunguiculata)in Nigeria. The research was conducted in Obafemi Awolowo University, Ile-Ife Osun State, Nigeria. The research used replicated randomized complete block design with treatments consisting of Zero-tillage (ZT), Reduced tillage (RT), Conventional tillage + Mulch (CT + ML) and Conventional tillage (CT). Exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$) were extracted with neutral solution of 1.0 M $NH_4OA_C$.. The $K^+$ and $Na^+$ concentrations in the extract were determined using the flame photometer while $Mg^{2+}$ and $Ca^{2+}$ were determined using the atomic absorption. Actual evapotranspiration ($ET_a$) was estimated using the soil water balance approach. Cowpea production on sandy loam top-soil can be optimally produced on Zero tillage system. Considering the profit over two years and the relative energy requirements, ZT system resulted in recording $ 573 profit, which was the highest profit margin among the treatments considered over the two growing seasons, RT ($ 89) had the least value.*

***Key words*: *tillage, volumetric moisture content, crop productivity, soil penetration resistance, evapotranspiration***

## INTRODUCTION

Management of soil tillage affects soil respiration, temperature, water content, pH, oxidation-reduction potential, and, available microorganisms [17]. Poor tillage practices could have detrimental effects on the physical, chemical, and biological properties of soils. In most farming communities, poor tillage directly affects soil aggregate, temperature, water, infiltration and retention [11]. These effects go beyond crop productivity and sustainability [19], emissions of greenhouse gas [32], deformation of soil structure and carbon (C) sequestration [12, 10]. Intensive tillage over a long period of time caused soil degradation, compaction, and loss of soil and soil organic matter (SOM) in many agroecological areas around the world. Good soil management practices, therefore, protect soil from water and wind erosion, as well as, provision of a good and weed-free seedbed for planting. It also destroys soil hardpans and compacted layers that could limit root development and maintenance, and increase organic matter content [35]. Cowpea is a plant that provides nitrogen to the soil system through $N_2$ fixation hence enriches itself with protein with or without external application of mineral nitrogen fertilizers [30]. The crop plays a vital role in the livelihood of many people dwelling in the developing world [9], being a rich source of protein and carbohydrates with high nutritive values [8, 34]. Apart from being a component of the conventional cropping systems in crop rotation plans, it is well suited to dry conditions owing to its adaptive capacity to various environmental stresses where other crops grow abnormally [7]. Soil physical quality is the capacity of a given soil to meet plant and environmental demands for necessities of water and aeration over time and to resist processes that might decrease that capacity [21]. Deterioration of soil physical property is facing unprecedented degradation under continuous land use and fast economic growth into agricultural lands thereby posing a threat to resource sustainability in Ile-Ife, Nigeria and other developing countries. There are three major crucial, and interdependent aspects of soil that affect crop productivity, these are biological, chemical and physical health. However, most times, soil's physical properties are given little or no attention while much attention is often given to the chemical and biological conditions. For instance, many commercial farmers use heavy farm machineries for land preparation without prior knowledge of the adverse effects of such practiceon soil quality [4]. This practice consequently has led to the removal of the productive topsoil and exposes sub-soils to further degradation. The suitability of soil for sustaining plant growth and biological activity is a function of its physical properties [14]. Various reports on soil degradation [26, 5, 3] indicated that plough and harrow are among the heaviest machines used for farming operations. The effects of these farm implements on selected physical and chemical soil properties were not encouraging. Information on response of cowpea to different tillage practices in African countries particularly Nigeria is very scarce. In this study, four tillage practices were studied in cultivating cowpea under rainfed conditions. The main aim of the study was to determine the effects of tillage practices on grain yields of cowpea in relation to economic value in Ile-Ife, south west Nigeria.

## MATERIALS AND METHODS

### Site Description

Field trials were conducted at the Teaching and Research Farm, Obafemi Awolowo University Ile-Ife, Nigeria (N 7° 31' E 4° 33') Nigeria with 244 m above mean sea level (a.s.l.), in 2018 and 2019. It is located in tropical rain forest, of Nigeria. Total annual rainfall in the study area is about 1,350 mm with a bimodal pattern typical of humid South of Nigeria.

The first cycle occurs from March and July while the second occurs from September and November.The average daily minimum temperature ranged between 20°C and 22°C and the average maximum temperature between 27°C and 35°C. The experimental site was under vegetation fallow for three years before the experiment started and guinea grasses dominated the bush where the investigation was conducted. The soil was deep, well drained and underlain by coarse grained granite gneisses bedrock. The soil is locally classified as Iwo series [31] and as an Alfisol [25].

The soil at the site is characterized by brownish gray colour with the surface texture varying from sandy loam to loamy sandy at sub-surface surface [31].

### Experimental Design and Layout

The experiments were conducted during the 2018-2019 for two consecutive rainy seasons on a gentle slope field (< 1 %).

The treatments consisted of four tillage practices: Zero Tillage (ZT), Reduced Tillage (RT), Conventional Tillage + Mulching (CT + ML), Conventional Tillage (CT), (Table 1).

They were arranged in a randomized complete block design in triplicate. The ZT and RT are the predominant practices by most of resource-constrained farmers in sub-Saharan Africa (SSA) who do not use much fertility inputs and lack of access to funds [36].

The CT and CT + ML represent the practices of the few resource-endowed farmers in SSA who can afford the cost involved and are located in high potential farming areas similar to the experimental site.

In order to have a fully replicated experiment for CT+ML, mulch was applied three weeks after ploughing and harrowing.

Table 1. Treatments and description

| Treatment | Description |
|---|---|
| **Zero Tillage (ZT)** | Plots were sprayed with mixed herbicides containing the active ingredient of dimethyl 2.4-D amine and Paraquat dichloride which each concentration was 825 g/L and 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water and 450 ml mixture of herbicide active ingredient herbicide Paraquat dichloride in the Knapsack sprayer. |
| **Reduced Tillage (RT)** | First plough (tillage depth of 12.5 cm) + spraying with herbicides containing the active ingredient dimethyl 2.4-D amine which concentration was 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water in the Knapsack sprayer. |
| **Conventional Tillage + Mulching (CT + ML)** | Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm) + mulch (7.5 t/ha Guinea grass (*Panicum maximum* grass residue) |
| **Conventional tillage (CT)** | Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm) |

Source: Explanation of the Treatments.

Early maturing cowpea variety, (IT89KD-288, 56-63 days) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, was planted on 21st September 2018 and 30th of August, 2019 at a target approximate population of 133,333 per ha (0.5 m x 0.30 m, two seeds per hole).

Weeds were controlled manually by using a local hand hoe and by hand picking. Cypermethrin, a pyrethroid compound was used to control insect fortnightly manually. Cypermethrin was applied 2 weeks after planting to control insects. Cypermethrin, was applied starting at two (2) weeks after sowing during cropping seasons and was repeated for four times consecutively.

The surface and subsurface soil layer, i.e. (0–15 and 15-30 cm) of the soil profile, were sampled because these layers control many critical and environmental processes, including seed germination and early seedling growth.

**Soil Sampling and Laboratory Analysis**

Soil samples were collected before land preparation to quantify the baseline status of the soil before the trial. Ten composite samples (0-15 cm soil depth) were taken randomly from the experimental site and bulked for laboratory analyses. This same process was repeated for 15-30 cm soil sample, before commencement of the experiment in the year 2018. The soil samples were air-dried at room temperature for some days and later crushed and sieved using 2 mm sieve before analysis. Chemical and physical soil analyses were carried out (Table 2).

Table 2. Physical and chemical properties of the experimental site prior to sowing cowpea

| **Parameters** | **Depth (cm)** | |
|---|---|---|
| | 0-15 | 15-30 |
| pH1:1 (Soil: Water) | 6.39 | 6.31 |
| Exchangeable cations (meq. 100 $g^{-1}$) | | |
| Exchangeable Ca | 0.95 | 0.93 |
| Exchangeable Mg | 0.34 | 0.30 |
| Exchangeable Na | 0.89 | 0.61 |
| Exchangeable K | 0.51 | 0.36 |
| Hydrogen ion ($H^+$) (meq. 100 $g^{-1}$) | 0.32 | 0.46 |
| Cation exchange capacity (CEC) | 2.69 | 2.20 |
| Effective cation exchange capacity ECEC (meq. 100 $g^{-1}$) | 3.01 | 2.66 |
| Total Nitrogen (%) | 0.25 | 0.28 |
| Soil particle size distribution (%) | | |
| Clay | 11.6 | 11.6 |
| Silt | 8.72 | 6.72 |
| Sand | 79.68 | 81.68 |
| Textural class | Sandy loam | Loamy Sand |

Source: Data from Laboratory.

Soil pH was determined with a glass electrode pH meter in distilled water using 1:1, soil: water [33]. Total nitrogen was determined by the macro-Kjeldahl method [6]; available phosphorus was extracted with Bray-1 P solution by the molybdenum blue method on Technicon auto analyzer as modified by [24].

Exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$) were extracted with neutral solution of 1.0 M $NH_4OA_C$. The $K^+$ and $Na^+$ concentrations in the extract were determined using the flame photometer while $Mg^{2+}$ and $Ca^{2+}$ were determined using the atomic absorption spectrophotometer (AAS). The exchangeable acidity ($H^+$) was extracted using 1.0 M KCl [28]. Aliquot of the extract was titrated with 0.05 M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of NaOH used was taken to be equivalent to the total amount of exchangeable acidity in the aliquot taken [22]. Cation exchange capacity (CEC) was estimated by the summation of exchangeable bases [13]. Particle size analysis was determined by hydrometer method [23].

**Evapotranspiration**

Actual evapotranspiration ($ET_a$) was estimated using the soil water balance approach [1, 16] in Equation (1).

$$ET_a = P - RO \pm \Delta S - D \quad (1)$$

where:
P is rainfall (mm);
RO is Runoff (mm);
ΔS is change of soil water storage in the root zone from 0 to 60 cm;
D is drainage (mm).

Surface runoff within area of 1 $m^2$ in the replicates was channeled to a graduated plastics container and measured after each rainfall. Drainage was determined from the soil moisture content measured at regular intervals.

**Water productivity**

Seasonal water productivity was determined using the Equation (2).

$$WP = \frac{Y}{ET_a} \quad (2)$$

where:
Y is marketable yield (t $ha^{-1}$);
$ET_a$ is actual crop evapotranspiration (mm).

**Yield of cowpea**

At physiological maturity, the cowpea pods within each plot were harvested and threshed manually and the seeds yield per plot were estimated. Grain yield was moisture corrected to 12.5 %.

**Statistical Analysis**

The data collected were subjected to analysis of variance (ANOVA) using SAS to assess treatments effects of tillage practices on crop yield. Differences between means were separated by using Duncan Multiple Range Test ($p$ = 0.05) [27].

## RESULTS AND DISCUSSIONS

**Chemical and physical properties of the soil prior to cultivation**

The soil pH (water) for 0-15 cm soil depth was 6.39 while that of 15-30 cm soil depth was 6.31 (Table 2). The soil was slightly acidic and can support the optimal growth of cowpea [29]. Such pH levels can substantially affect the availability of nutrients through its effect on soil microbial activity [2]. The cation exchange capacity (CEC) of the top and sub-soil with values of 2.69 and 2.20 meq.100 g-1 respectively. Total N of top soil (0.25 %) and sub-soil (0.28 %) were above the critical value of 0.11 %. Total Nitrogen was generally sufficient in the soil samples [15]. The percent sand in 0-15 cm soil depth was 79.68 while the sand content in 15-30 cm soil depth was 81.68 %. Silt was 8.72% at the top soil and 6.72 % at the sub-soil (Table 2). The soil texture for both top and sub soil was stated in Table 2.

**Evapotranspiration**

There were variations in the seasonal crop water use of the treatments. The total rainfall in the first season was 238 mm and was considerably lower than that of the second season, 775 mm (Table 3).

Table 3. Water productivity for the two growing seasons

| Year | Treatment | Yield ($kg\ ha^{-1}$) | Evapo-transpiration (mm) | Water productivity ($kg\ m^{-3}$) |
|---|---|---|---|---|
| 2018 | CT | $210 \pm 14^a$ | $166 \pm 9^a$ | $0.79 \pm 0.02^b$ |
| | ZT | $172 \pm 18^b$ | $181 \pm 18^a$ | $1.05 \pm 0.11^a$ |
| | CT+ML | $166 \pm 13^b$ | $176 \pm 16^a$ | $0.60 \pm 0.02^b$ |
| | RT | $292 \pm 9^a$ | $172 \pm 11^a$ | $0.53 \pm 0.05^b$ |
| 2019 | CT | $596 \pm 10^a$ | $651 \pm 5^a$ | $1.09 \pm 0.06^b$ |
| | ZT | $563 \pm 16^a$ | $663 \pm 23^a$ | $1.18 \pm 0.06^b$ |
| | CT+ML | $578 \pm 18^a$ | $649 \pm 12^a$ | $1.12 \pm 0.02^b$ |
| | RT | $384 \pm 15^b$ | $650 \pm 21^a$ | $1.69 \pm 0.08^a$ |

Source: Primary Data: Data gotten from the experimental field.
Note: Means within a column (for each treatment factor) not sharing a lowercased italic letter differ significantly at the P < 0.05 level.

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Hence lower evapotranspiration in the first season compared with the second season. The seasonal evapotranspiration for all the tillage practices were not significantly different in the two seasons despite their variations. In the first season, zero tillage had the highest water productivity while in the second season; minimum tillage had the peak water productivity and was significantly higher than the water productivities of other tillage practices.

The water productivity under CT + ML and RT compares well with). [20]. However, the water productivity for other tillage practices were higher than those in. [20].

The water productivity in the second season was higher and could be attributed to higher seasonal rainfall.

**Grain yield**

Higher yields were recorded for 2019 growing season for all the treatments (Figure 1).

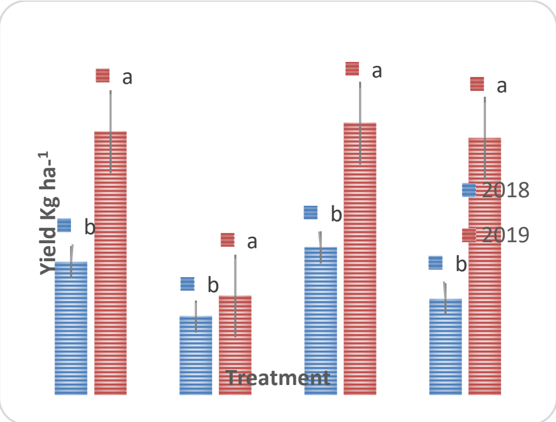


Fig. 1. Mean values of grain yield of cowpea for 2018 and 2019 cropping season in response to different tillage practices

Source: Primary Data: Data gotten from the experimental field.

ZT had an increase of 168 % in the grain yield at the end of second cropping season, the highest among the tillage practices examined, followed by CT+ML (98 %) and CT (84 %); RT had the least increase value of 26 %. In addition, there were significant differences in the cowpea grain yields when the average after two years was considered. The highest (460 kg ha-1) and the lowest (195 kg ha-1) mean values of grain yield for the two seasons were obtained on plots subjected to the CT and RT treatment respectively (Figure 2).

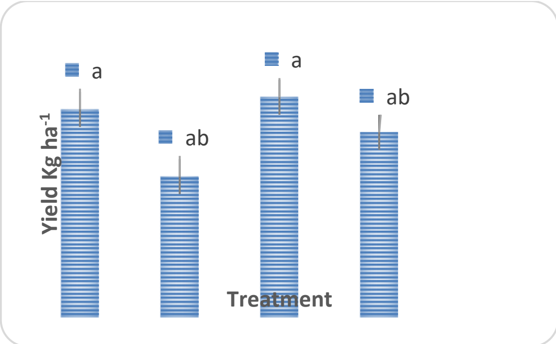


Fig. 2. Mean grain yield of cowpea over the two cropping seasons in response to different tillage practices

Source: Primary Data: Data gotten from the experimental field.

**Cost analysis**

Table 4 shows that plots subjected to the CT+ ML treatment had the greatest input cost of 221.53 USD during the 2018 cropping season, while plots subjected to the ZT treatment had the lowest input cost of 111 USD Similarly, for the 2019 cropping season, the highest (224 USD) and lowest (113 USD) input costs were obtained on CT+ ML and ZT plots, respectively.

Table 4. Cost analysis of different tillage practices

| Treatments | Activities | Cost implication (USD $ha^{-1}$) |
|---|---|---|
| CT | 2-plough, harrow, manual weeding, cowpea seed, insecticide, harvest | # 77,750.00 (213.30-2018, 215.97-2019) |
| CT+ML | 2-plough, harrow, mulching, manual weeding, cowpea seed, insecticide, harvest | # 80,750.00(221.53-2018, 224.31-2019) |
| ZT | 2 bottles of Herbicides, manual weeding, cowpea seed, insecticide, harvest | # 40,500 (111.10-2018, 112.5-2019) |
| RT | 1-plough, 1 bottle of herbicides, manual weeding, cowpea seed, insecticide, harvest | #56,500(155.00-2018, 156.94-2019) |

Source: Primary data.

The CT+ ML treatment had a higher input cost than the ZT treatment because cost of hiring tractors coupled with labor involved in mulching are more expensive in Nigeria than using herbicides.

Because the RT required one tillage operation, the CT had a greater input cost than the RT.

The additional tillage operation raises the energy need of the CT when compared to the RT, in addition to raising the input cost.

The seed yield for a given tillage practice has a direct relationship with the money earned for that tillage treatment [18].

**The income analysis** for the 2018 and 2019 growing seasons for the various tillage treatments was presented in Table 5. The maximum income for the 2018 cropping season was obtained on CT and CT+ ML plots respectively, at 333.72 and 300.35 USD. Similarly, the greatest revenue of $614 and $595 for the 2019 season was obtained on CT and CT+ ML plots, respectively. Reduced tillage plots had the least income, $177 in 2018, and $223 in 2019 (Table 5).

Table 5. Yield and income of the different tillage practices

| Treatments | 2018 | | 2019 | |
|---|---|---|---|---|
| | Yield Kg $ha^{-1}$ | ($ $ha^{-1}$) | Yield Kg $ha^{-1}$ | ($ $ha^{-1}$) |
| CT | 324 | 334 | 596 | 614 |
| CT+ ML | 292 | 300 | 578 | 595 |
| ZT | 210 | 217 | 563 | 580 |
| RT | 172 | 177 | 217 | 224 |

Source: Primary Data: Data gotten from the experimental field.

**The profit** associated with each tillage treatment, which is calculated as the difference between the revenue generated and the input cost was shown in Table 6.

The highest profit earnings of 120 USD were obtained on CT plots for the 2018 while ZT ($468) had the highest earning in 2019 cropping seasons.

The lowest profits of $ 22 and $66.98 for the 2018 and 2019 seasons respectively, were obtained on RT plots (Table 6).

Table 6. Profit margins analysis of different tillage treatments ($ $ha^{-1}$)

| Treatments | Income | | | Cost | | | Profit | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | Sum over 2 years | 2018 | 2019 | Sum 2 years | 2018 | 2019 | Sum of over 2 years |
| CT | 335 | 614 | 948 | 213 | 216 | 429 | 120 | 398 | 519 |
| CT+ ML | 300 | 595 | 895 | 222 | 224 | 446 | 79 | 371 | 449 |
| ZT | 217 | 580 | 797 | 111 | 113 | 223 | 106 | 468 | 573 |
| RT | 177 | 224 | 401 | 155 | 157 | 312 | 22 | 67 | 89 |

Source: Primary Data.

## CONCLUSIONS

Overall, the ZT had $573, which was the highest among the treatments considered as profit margin over the two years which was the largest profit margin among the treatments considered. This was followed by CT (519 $) and CT + ML ($449), RT ($89) had the least. Therefore, ZT practices should be carefully adopted in sandy loam - loamy sand soils to prevent soil compaction at this depth over time. Considering the profit over two years and the relative energy requirements, ZT with $573, was found to be the most suitable tillage method for the optimum cultivation of cowpea on tropical sandy loam soil. Despite the fact that traditional tillage management approaches have gained a lot of attention in African countries in recent years, more research are needed on a variety of textured soils in various agro-ecological zones in Africa to provide food security at a low cost.

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# ECONOMIC ACTIVITY OF THE RURAL POPULATION: A CASE STUDY OF UKRAINE

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***Abstract***

*In the article determined and substantiated that the public opinion that the residents of rural areas, due to less strict observance of the regime of quarantine COVID restrictions on economic activity, lower population density in the settlement network, and technological features of agriculture, suffered smaller losses in terms of employment and income than other strata, turned out to be too optimistic. According to the results of the study, social alienation is increasing as a result of the deterioration of the entire spectrum of social and labour relations. Further research on the chosen subject may be related to strengthening the institutional capacity and financial self-sufficiency of communities due to the decentralization of powers and resources, the transition to a two-level model of inter-budgetary relations, the development of local self-government and changes in the administrative-territorial system, overcoming the social alienation of self-employed persons, provision of force majeure in circumstances similar to the COVID pandemic, economic access to food, health care services, education, culture, transport, and digital infrastructure.*

**Key words:** *agricultural sector, rural population, economic activity, COVID restrictions, employment, labour relations*

## INTRODUCTION

Research on the peculiarities of the economic activity of the rural population focuses on the influence of a number of various factors on this process. At the same time, some of them have a direct and quick effect, while others have a long-term effect. The specificity of the formation of the economic activity of the population of Ukraine consists of a series of successive systemic economic crises that occurred since 2001, which had a negative impact on the socio-economic sphere and the quality of life of the country`s rural population. In addition, the unfolding of such economic crises significantly worsened due to the overlap of world global crises. As a result, all these negative phenomena negatively affected the processes of the formation of economic activity of the rural population. And even recent events related to Russia`s armed aggression against Ukraine impose significant negative consequences on the processes of economic activity of the rural population. However, the study of this impact requires in-depth analysis after receiving relevant statistical data in the future.

The main problem that affected the level of economic activity in the countryside was the long-term processes of reducing production volumes in agriculture and the transformation of agrarian business in general, which continued in the early 2000s. The consequence of these trends was the growth of negative social changes in the countryside, the migration of a large part of rural residents to cities, etc. All this led to the aggravation of the problem of economic activity of the population in the countryside, and an increase in the level of unemployment, which led to a decrease in the incomes of rural residents. At the same time, the active formation of large agricultural holdings in the 2010s was associated with the technical re-equipment of agriculture, which was accompanied by the release of surplus labour.

Thus, solving the problems associated with a significant increase in the number of jobs is directly related to the implementation of important economic tasks in the agricultural sector.

At the same time, the difficult situation with the use of the labour force is connected not only with the growth of agricultural efficiency but also with the formation of a labour market with a high level of professional mobility of the population.

All this requires a detailed analysis of the current situation and the development of recommendations for increasing the efficiency of the use of the economically active population of rural areas.

The study of the problems of economic activity or inactivity of the rural population, their distribution by appropriate groups, and the analysis of factors that affect the level of unemployment and working capacity of peasants are not new to the field of specialized economic scientific research and are sufficiently widely disclosed in the works of such scientists as O. Agres [1], O. Apostolyuk [2], I. Balaniuk [3], O. Binert [4], A. Boiar [5], Y. Chaliuk [6], M. Dziamulych [8, 9, 10, 11, 12, 13, 14, 15], V. Nahornyi [16], N. Onyshchenko [18], A. Popescu [19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30], G. Shamborovskyi [31], T. Shmatkovska [32, 33, 34, 35], R. Sodoma [36, 37, 38, 39], O. Stashchuk [40, 41, 42], A. Tiurina [44], I. Voronenko [45, 46], I. Yakoviyuk [47], Y. Yanyshyn [48], O. Yatsukh [49] and others.

However, the constant changes taking place in the socio-economic sphere, as well as the development of agricultural production in Ukraine, require an in-depth study and analysis of the grouping of the rural population by activity levels; determination of employment indicators, and the level of unemployment of rural residents; study of the influence of the quality of the received education on the economic activity of the peasants.

## MATERIALS AND METHODS

The economically active population is a part of the population of both sexes, which during a certain period ensures the supply of its labour force for the production of goods and the provision of services.

Those engaged in economic activity are persons aged 15–70 who perform work for remuneration under the conditions of full-time or part-time employment, work individually (self-employed) or for individual citizen-employers, in their own (family) enterprise, members working without pay households, employed in personal auxiliary agriculture, and also temporarily absent from work. According to this methodology, persons who worked for at least 4 hours per week (at least 30 hours on a personal farm) regardless of whether it was permanent, temporary, seasonal, casual, or other work, are considered employed.

The unemployed (as defined by the International Labour Organization) are persons aged 15–70 (both registered and unregistered in the state employment service) who simultaneously meet three conditions: they do not have a job (gainful occupation), are looking for work or are trying to organize own business, ready to start work within the next 2 weeks. This category also includes persons who are studying under the referrals of the employment service, have found a job and are waiting for an answer, or are preparing to start it, but at this time are not yet working.

Economically inactive population (population outside the labour force) - persons who do not have a job and are not looking for it, that is, they cannot be classified as “employed” or “unemployed” [7].

Unemployed population – persons aged 15-70 who were unemployed or economically inactive during the surveyed week.

When summarizing scientific-methodical approaches, formulating intermediate and final conclusions and proposals, techniques of abstract-logical tools, analysis, synthesis, analogy, comparison, etc. were used in the research.

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## RESULTS AND DISCUSSIONS

A decrease in the level of employment of the population and its economic activity negatively affects the dynamics of macroeconomic indicators. The share of the GDP of agriculture, forestry, and fisheries (according to the production method in actual prices) in the 1st quarter of 2021 was 2.8% compared to 2.9% in 2020 and almost 3% in the same period of 2019 to the total [17]. This is despite the fact that the chain index (month to previous month) of consumer prices for the specified period for food products and non-alcoholic beverages grew every year. As a matter of fact, we have a relative decrease in the production of agricultural enterprises compared to other sectors of the economy, in particular, due to unemployment and a decrease in the economic activity of employees. According to the State Statistics Service of Ukraine, the number of the workforce, i.e. all employed and unemployed persons aged 15 and older, in rural areas, which provided supply on the labour market during the surveyed week, in the first quarters of 2019-2021 remained almost unchanged and ranged from 52.1% (2021) to 53.8% (2020). At the same time, there was a decrease in of persons of working age (women aged 15-58 years and men 15-59 years old) in the 1st quarter of 2021 by 145 thousand compared to the corresponding period of 2019, of which the age category 20-64 years – by 106.3 thousand, which was 73.3%.

The explanation for this phenomenon can be the resumption of migration processes both in the middle of the country and outside it as a result of the relaxation of quarantine restrictions in 2021 and the start of mass vaccination.

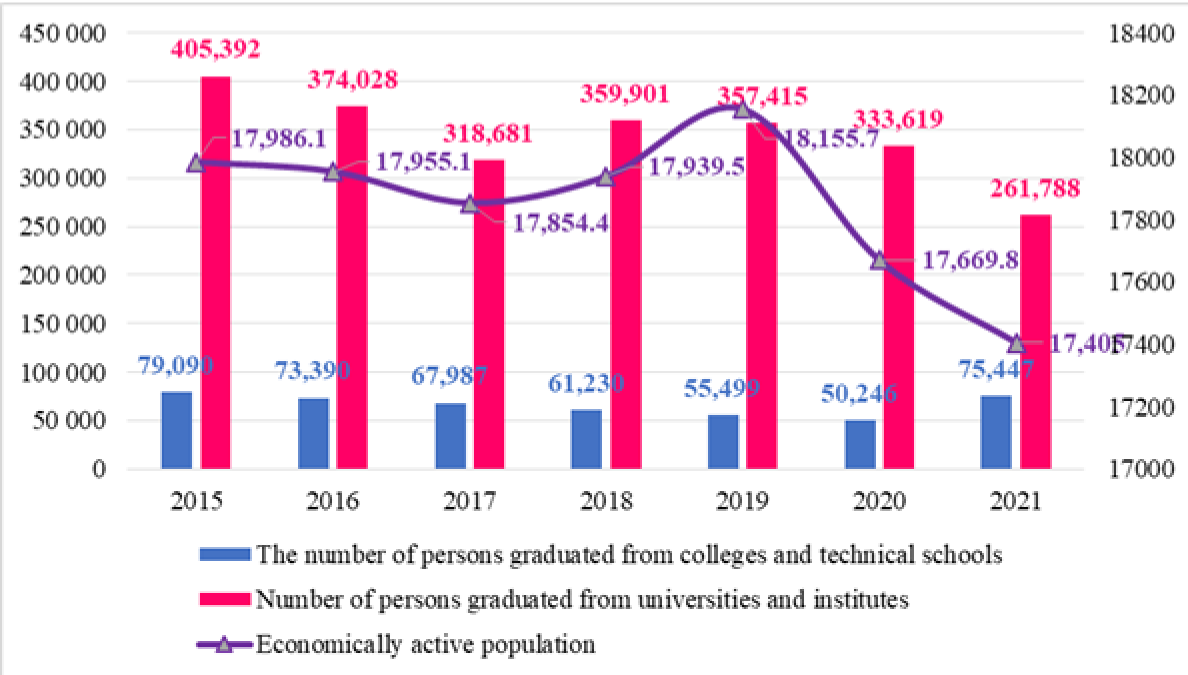


Fig.1. Dynamics of the number of the economically active population, persons who graduated from colleges and technical schools and persons who graduated from universities and institutes in Ukraine for 2015-2021, thousands of persons
Source: calculated and constructed according to data [43].

Using the data of the State Statistics Service of Ukraine, models were built that reflect the dependence of the number of economically active population aged 15-70 on graduation from educational institutions and the demographic situation in the country.

$$Y = 12{,}288.4794 + 48.0279X_1 + 8.5791X_2 \quad \text{.......................................................(1)}$$

where:

Y – the number of the workforce, thousands of people;

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$X_1$ – number of persons who graduated from colleges and technical schools, thousands of persons;

X2 – number of persons who graduated from universities and institutes, thousands of persons.

The model shows that the number of persons who graduated from institutions of higher education has a positive effect on the number of the economically active population, therefore, a balanced interaction of the education system and the labour market will lead to an improvement in the situation in the latter and contribute to an increase in the quality of the workforce. This is confirmed by the calculated elasticity coefficients, which are equal to:

$$E_{y/x1} = \frac{\partial y}{\partial x_1} \times \frac{\overline{x_1}}{\bar{y}} = a_1 \times \frac{\overline{x_1}}{\bar{y}} = 0.2672....(2)$$

$$E_{y/x1} = \frac{\partial y}{\partial x_2} \times \frac{\overline{x_2}}{\bar{y}} = a_2 \times \frac{\overline{x_2}}{\bar{y}} = 0.1434$$
.....................................................................(3)

Thus, the following conclusions can be drawn:

– a 1% increase in the number of persons who graduated from colleges and technical schools, all other things being equal, will cause an increase in the number of the economically active population by an average of 0.27%;

– an increase in the number of university and institute graduates by 1%, other things being equal, will cause an increase in the number of the economically active population by an average of 0.14%.

The presented results generally correspond to the current state of the labour market, which presents an increased demand specifically for graduates of colleges and technical schools. (Fig. 2). As we can see, in 2021, compared to the same period of the previous year, there was a reduction in the number of employed rural population by 361.7 thousand people, or by 7%, including wage earners by 153 thousand, and employers by 4.5 thousand.

Collapse business has become the most alarming signal about the effectiveness of state measures aimed at supporting micro and small enterprises in rural areas during the lockdown period associated with COVID-19.

The release of workers from agricultural enterprises, including due to COVID-19, led to a significant increase in unemployment among the rural population in 2020–2021 (Fig. 3).

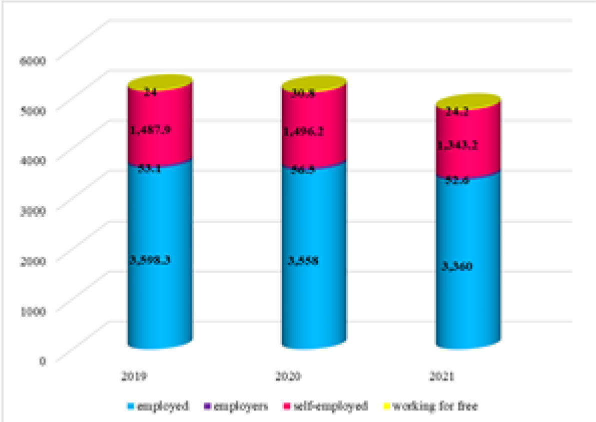


Fig. 2. The number of the employed rural population in Ukraine by employment status in 2019–2021, thousands of people
Source: [43].

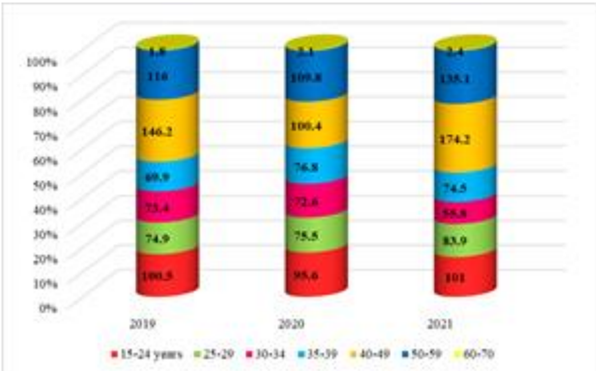


Fig. 3. Unemployment within the rural population of working age in Ukraine (according to the ILO methodology) for 2019-2021, thousands of people.
Source: calculated and constructed according to data [43].

As you can see, out of the seven analyzed age groups, the unemployment rate has increased in six, with the exception of 30-34-year-olds. For unknown reasons, the population aged 25–29 (+2.8%), 15–24 (+2.4%), and 40–49 (+2.1%) turned out to be the most vulnerable in terms of keeping their workplace. In our opinion, internal pendulum labour migrants could hardly compete with them. According to expert assessments, there was no mass influx of workers from abroad into rural areas

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either, and those who returned, as a rule, were in no hurry to find a job and were looking for various opportunities to return back as soon as possible. This is confirmed by the data of the National Bank of Ukraine, according to which in 2020, compared to the same period in 2019, remittances to Ukraine increased by more than 2.6% (from 8.701 to 8.928 billion USD). From this amount, private transfers from persons working abroad for more than one year increased by 7.5% (from 677 to 728 million USD). The constant leader among countries remains Poland, whose share in total revenues is almost a third - 30.3%, although a decrease of 8.3% is observed over the same period [20]. Analytical data from the State Statistics Service of Ukraine (Fig. 4) show that in agriculture, the number of persons who had the status of unemployed in 2021 was equal to 119.8 thousand, or more than every fifth of all workers who worked in the economy of the country.

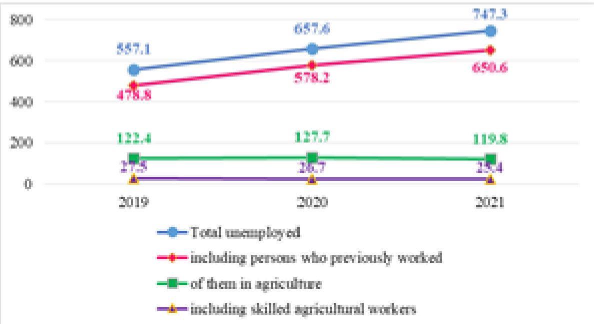


Fig. 4. The number of persons who had the status of unemployed in Ukraine in 2019-2021, thousand persons.
Source: calculated and constructed according to data [43].

As we can see, in contrast to the general dynamics of the labour market, the number of registered unemployed, including qualified workers, in the specified industries decreased by 2.6 and 2.1 thousand people, respectively, during the analyzed period. So, we can conclude that, despite the quarantine measures, the demand for agricultural workers has decreased compared to other industries, but not critically. However, this may not be true, since, for various reasons, not all unemployed people in rural areas turn to employment centres for help, and those who turn to them may not receive the appropriate status even in the conditions of a pandemic, both objectively and subjectively. objective reasons. The increase in unemployment among officially employed residents of rural areas has expectedly increased the burden on the expenditure part of the mandatory state social insurance fund in case of unemployment. In total, during the period when quarantine restrictions were in effect, the number of service recipients increased by 20% from 509.2 thousand in 2019 to 611 thousand in 2021 (Table 1).

Table 1. Provision of services by the State Employment Service of Ukraine to residents of rural areas in 2019–2021, thousands of people

| Indicators | 2019 | 2020 | 2021 | Deviation 2021 to 2019 | |
|---|---|---|---|---|---|
| | | | | thousands of people | % |
| Received services | 509.2 | 539.5 | 611.0 | 101.8 | 120.0 |
| Had the status of unemployed | 246.5 | 269.1 | 326.3 | 79.8 | 132.4 |
| In total, got a job, incl. before acquiring the status of unemployed | 126.9 | 103.4 | 99.2 | -27.7 | 78.2 |
| Underwent professional training | 46.3 | 32.6 | 30.0 | -16.3 | 64.8 |
| Participated in public and other works of a temporary nature | 51.2 | 34.5 | 23.0 | -28.2 | 44.9 |
| Number of unemployed persons covered by vocational guidance services | 232.9 | 221.2 | 275.8 | 42.9 | 118.4 |
| Received unemployment benefits (at the end of the period) | 107.7 | 146.2 | 150.5 | 42.8 | 139.7 |

Source: calculated and constructed according to data [43].

As we can see, the unfavourable situation during the COVID-19 pandemic had a negative impact on the volume of employment, including before the client became unemployed. Other active types of services of the State Employment Service decreased, namely: vocational training – up to 64.8% and participation in public works – up to 44.9%. Therefore, despite the systematic and operational measures of the state, in extreme conditions, the rural unemployed found themselves in a kind of institutional trap. On the one hand, they were released, depriving them of the basic means of subsistence, while on the other hand, opportunities for employment and finding a new place of work were significantly narrowed.

## CONCLUSIONS

It has been established that the public opinion that the residents of rural areas, due to less strict observance of the regime of quarantine COVID restrictions on economic activity, lower population density in the settlement network, and technological features of agriculture, suffered smaller losses in terms of employment and income than other strata, turned out to be too optimistic As a result of the introduction of two all-Ukrainian lockdowns in 2020-2021, the number of the employed rural population decreased by 361,000 people, or by 7%, of which 198,000 were employed and 153,000 were self-employed. The unemployment rate during the specified period also increased by 1.7 percentage point, or up to 11.5%. In April-May 2021, almost 120,000 workers, or one in five of the total in the economy, received the status of unemployed, dismissed from agricultural, forestry, and fishing enterprises. At the same time, the number of applicants for one vacancy in rural areas has doubled due to a simultaneous reduction in the financial capabilities of the State Employment Service, especially regarding the implementation of active forms of returning them to employment status. In the conditions of the pandemic, the state and local authorities have become even more distant from the vital problems of the self-employed in rural areas. Social alienation is increasing as a result of the deterioration of the entire spectrum of social and labour relations. In the first half of 2020, compared to the same period of the previous year, the share of the population with average per capita equivalent monthly income lower than the legally established and the actual living wage increased from 2.7 to 3.3% and from 33.6 to 34, 7% respectively. As a result, the well-being of rural households worsened, the scale of poverty increased, and the problem of economic access to food products became even more acute for certain categories. Further research on the chosen subject may be related to strengthening the institutional capacity and financial self-sufficiency of communities due to the decentralization of powers and resources, the transition to a two-level model of inter-budgetary relations, the development of local self-government and changes in the administrative-territorial system, overcoming the social alienation of self-employed persons, provision of force majeure in circumstances similar to the COVID pandemic, economic access to food, health care services, education, culture, transport, and digital infrastructure.

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# INNOVATIVE DEVELOPMENT OF RURAL TERRITORIES AND AGRICULTURE IN UKRAINE

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***Abstract***

*The socio-economic aspects of rural development in the context of decentralization of management, features of the organization of rural areas and the formation of potential for development is considered in the article. The necessity of intensifying activities in the direction of decentralization of power and introduction of modern principles of economic reform of rural areas is substantiated. The process of greening of agricultural production has been confirmed. The structure of production of the main types of agricultural products by agricultural enterprises and their profitability are considered. A quadratic trend model of the dynamics of the volume of profits of business entities in rural areas has been developed. Sufficient attention is paid to the formation and justification of scientific solutions aimed at building a new, more effective model of rural development management in Ukraine. Risks and threats to the development of entrepreneurship in rural areas have been identified and the probability of influencing the level of socio-economic development of rural areas has been substantiated. It is important to note that in order to increase the effectiveness of business policy, it is necessary to determine the main criteria that will shape the development of rural areas on the basis of the formed forecast indicators and determined factors influencing them. A number of important positions that influence directly or indirectly on the implementation of innovative projects of development of rural areas have been proved, in particular, the greatest weight have their own resources, which can be used in communities. On the basis of the conducted researches the whole model of innovation development is proposed, which includes all spheres that influence the development of entrepreneurship in rural areas.*

***Key words:*** *rural areas, innovative development, risks, opportunities, stimulating determinants, profitability, agricultural enterprises*

## INTRODUCTION

In modern conditions, the development of agriculture is based on a significant update of agricultural technologies according to market needs [15], that is why the need for human labor is decreasing and the number of employed rural population is also decreasing. This creates the relevance of the study of the prospects of rural areas in Ukraine.
The traditional benefits of economic activity in rural areas will be continue to depreciate. It affects negatively to the quality and standard of living of the rural population and the general prospects for rural development.
From a scientific point of view, an important problem is the ability to form and approve scientific solutions aimed at creating more effective model of rural development management in Ukraine. Given the need to ensure the competitiveness of rural areas for business in modern conditions, this development should be aimed at creating a favorable environment for the introduction and dissemination of innovation, encouraging enterprises to innovate in rural areas. This

requires optimization in the management system of rural development, through the development of an innovative model that will be scientifically sound, which will serve as a challenge in the study. Scientific aspects and practical problems of solving this problem are investigated in scientific works by A. Popescu, T. Yu. Dubnevych, Dinu, E. Stoian V.Serban, T.Shmatkovska, M. Dziamulych, N.Vavdiiuk, N. Kutsai, V. Polishchuk, V. Dushka, V. Yakubiv and other researchers [5, 6, 7, 8, 9,10, 11, 12, 13, 14, 15].

It should be noted the contribution of domestic researchers in the development of theory and methodology of innovation management, in particular Kulagina N., Ch. Pencea [3, 4]. Successful attempts were also made to theoretically comprehend and form practical solutions to the issues raised in the article of optimizing the management of territorial development in the works of such scientists as F. Vazhynsky, V. Zalizko, V. Martynenkov, R. Sodoma,, O.Agres,, O.Havryliuk, K. Melnyk [19, 20, 16]. Regarding the specifics of innovation development management in rural areas, the works of R. Khaled, W. Gotry, M.I. Ignatko [2, 1].

According to N.A. Kulagina [3], innovative component of development in agriculture contributes to ensuring the competitiveness of rural products through the development and implementation of innovations [3, p.104]. Of course, it is worth agreeing with the position of N.A. Kulagina, but in our opinion it is appropriate to focus on the development of agricultural business in the countryside, this will help attract new business ideas, new startups and increase opportunities for doing business in the countryside. Therefore, the introduction of digital literacy for the population, the provision of more information on new opportunities and an innovative toolkit in social communications of modern business is aimed at improving the infrastructure in the countryside.

The availability and content of a large number of studies on the problem of innovation management, stimulating innovation development, ensuring the effective creation, implementation and dissemination of innovations indicate not only the scientific interest in the problems of development management on the basis of innovation, but also on the tangible need of market participants in the use of their results in management practice, in particular the management of rural development.

The authors show that the peculiarities of rural development in the context of agrarian business environment are factors that affect the configuration and structure of the mechanism for managing rural development in modern conditions. It is possible to optimize the system of proper management of rural development in Ukraine at the current level.

## MATERIALS AND METHODS

The theoretical and methodological basis of the study is a systematic approach to the study of the fundamental provisions of economics in relation to the development of entrepreneurship in rural areas in terms of innovative changes.

Methods of analysis and synthesis, scientific hypotheses, grouping, analysis, system approach, time series, logical method and etc. were also used in the research process. The process of scientific research is based on general scientific and special economic methods. The abstract-logical method is used to formulate basic principles, theoretical generalization of conclusions and analysis of research results of other researchers, clarification of the conceptual and categorical apparatus. The use of sociological methods allowed to monitor the business environment in rural areas. Characteristic of entrepreneurial formations and assessment of entrepreneurial activity in rural areas was carried out using the economic-statistical method. In order to substantiate the business environment and determine the strategic orientations of business, the method of SWOT analysis was used. Within the economic-mathematical method, the methods of correlation-regression analysis and modeling are used. Graphic and tabular techniques are used to visualize the results.

The reliability of the obtained results, conclusions, and proposals is based on a comprehensive analysis of statistical data and scientific generalizations.

## RESULTS AND DISCUSSIONS

Management is carried out with the help of certain tools, namely regulatory, administrative and socio-economic.

By using the tools to prevent or minimize the impact of macro-environmental changes on rural development, formulating an action plan and monitoring its implementation within the rural development management system, the problem of hopelessness of rural development can be solved. Ukraine in which agriculture is an important component of the domestic economy, where the field of agricultural innovation management is important, but not the only sector that needs improvement that will significantly affect the development of rural areas of Ukraine [1, p. 20.]. Significant changes have taken place in the context of decentralization and reform of the management system.

Innovation can be considered from two conceptual positions:

1) the process which is carried out in a certain order and has features that allow you to explain it in terms of process method;

2) new products are some improvements that are the result of the implementation of the innovation process.

Agricultural innovations play an important role in promoting the modernization of agricultural products and significantly improving the quality of agricultural products. They are based on ideas and concepts, the process of development and implementation, as well as the implementation of new technologies. Modern production methods that take into account the interests of potential consumers. Such innovations cover everything related to the creation, demonstration of innovative ideas, usually ending with the implementation of innovation in practice, such as:- conquest of new markets for environmental products; - making profits from the implementation of environmental innovations; - formation of corporate ecological image; - increase employment through job creation; - rational use of natural resources. Therefore, the essence of eco-oriented entrepreneurship in rural areas is usually the same as traditional entrepreneurship (taking into account the subjectivity of the economy), but the emphasis is on the ecological form. Considering that the environmental utility of this type of business is a significant share of the overall utility, it is logical to say that the body of environmental business should be considered as the main body. The relationship of the greening of agricultural production with economic, social, and environmental systems is shown in Figure 1.


Fig. 1. The relationship of the greening of agricultural production with economic, social, and environmental systems
Source: adapted from [4].

In rural development management, we focus on changes in the organizational structure, management methods, and ways of serving and meeting the needs of the population and businesses. The interrelation between greening is close to social (welfare), economic (maximum profit at minimum cost), and environmental (improving the environment and increasing soil fertility).

Innovative rural governance must take an integrated approach, which means that the reorganization of the management system requires the integration and coordination of many success factors, namely leadership, organizational structure, processes, infrastructure, and human resources.

Supporting the development of innovation in certain areas makes it possible to obtain a specific effect that is important for ensuring the development of rural areas.

Therefore, building an effective digitalized infrastructure is important in managing rural innovations, for this we highlight the following areas:

- improving the conditions of economic activity in rural areas and living conditions of the rural population by reducing legislative and administrative restrictions on the use of IT infrastructure for doing business, gaining knowledge, implementing innovative ideas;
- presentation of the activities of public administration bodies through ensuring easy access to public information.

Innovations that will affect the development of rural areas include modification, improvement of administrative services provided to businesses and the population in this area. Prominent are e-services, which significantly simplify work in rural areas and require a reduction in human participation and time. However, the introduction of modern technologies in rural areas requires a modern hardware platform, the purchase of the necessary software, and the organization of trainings to increase the competence of officials. Modern technologies should increase the efficiency of public administration and self-government.

Modern technologies should help increase the efficiency of public administration and autonomy. The implementation of innovations is shown in Figure 2.

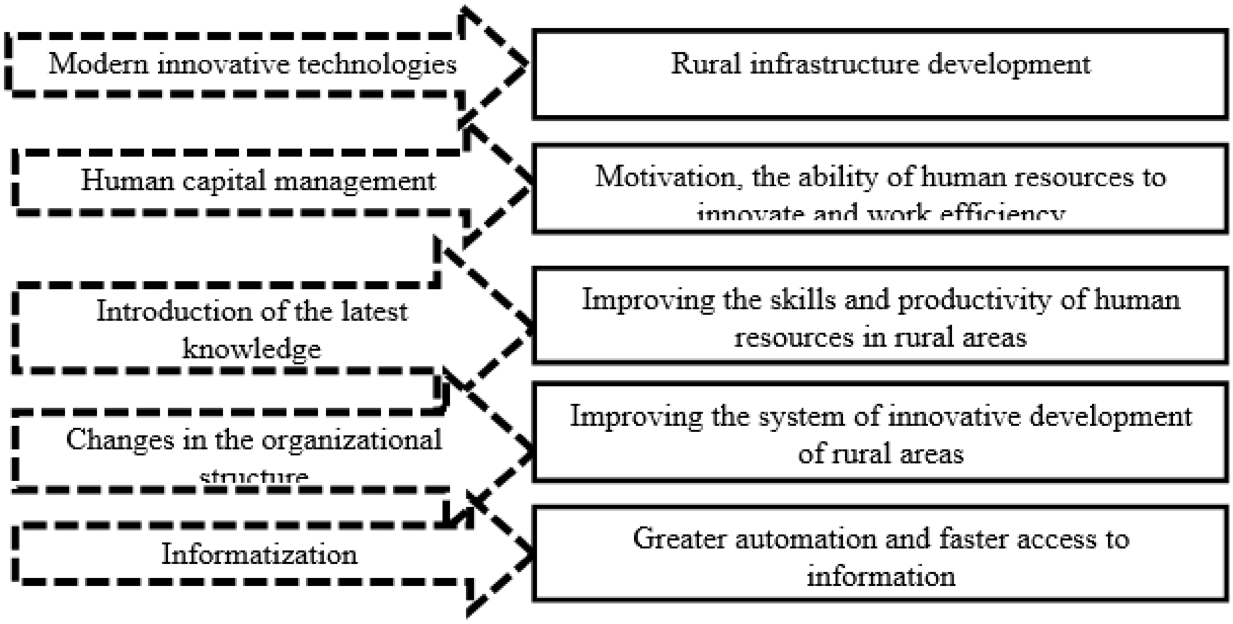


Fig. 2. Implementation of innovations for rural development
Source: own development.

In the case of rural areas, product innovations that can have a significant impact on the development of these areas include the modification and improvement of administrative services provided to businesses and the population in the area. The task of innovation and development management is to provide customers with new opportunities,

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so e-services have become important, which greatly simplifies work in rural areas and requires less manual involvement and time.

However, the introduction of modern technologies in rural areas requires a modern hardware platform, the purchase of necessary software, training to improve the skills of officials.

In modern conditions, measures for innovative development of rural areas should be complemented by projects of integrated and sustainable development. The innovative model of rural development provides for the creation of regional model centers for rural development, which include not only agriculture but also local industry, construction, trade, tourism, social services. Without this, it is impossible to increase the efficiency of the economy and improve living conditions in rural areas.

As for households, they produce most agricultural products, such as honey and potatoes (over 95%), vegetables (about 86%), fruits and berries (about 80%), milk (over 75%). Like farms, families that also cultivate small areas of agricultural land may switch to producing such products in the future. This indicates the feasibility of analyzing their functional status and characteristics in rural areas. The structure of production by agricultural enterprises of the main types of agricultural products in Ukraine in 2021 is shown in Figure 3.

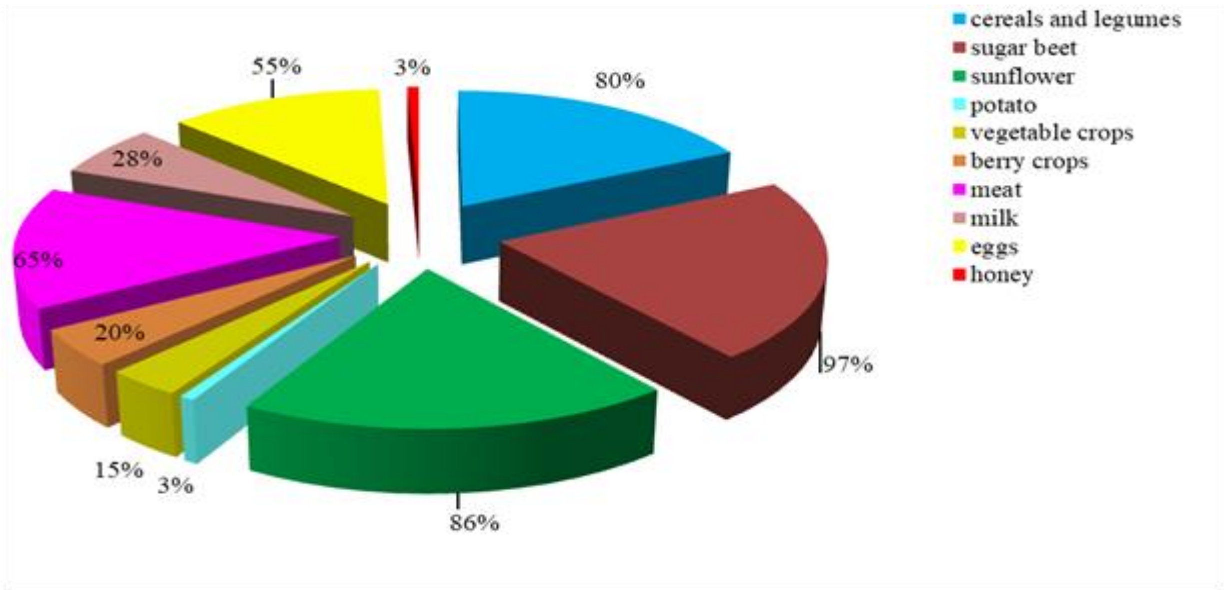


Fig. 3 Structure of agricultural production of the main types of agricultural products in Ukraine, 2021
Source: own development.

Table 1. Profitability of agricultural enterprises by their size

| Years | Profitability of operational activity of enterprises,% | | | | Profitability of all activity of enterprises | | | |
|---|---|---|---|---|---|---|---|---|
| | large enterprises | medium enterprises | small enterprises | of which microenterprises | large enterprises | medium enterprises | small enterprises | of which microenterprises |
| 2016 | 54.3 | 37.8 | 41.4 | 36.2 | 45.4 | 23.4 | 32.4 | 30.9 |
| 2017 | 29.3 | 30.4 | 37.2 | 33 | 24.7 | 21.6 | 30 | 26.5 |
| 2018 | 24.6 | 20.8 | 24.1 | 24.2 | 20.5 | 15.4 | 15.6 | 7.7 |
| 2019 | 22.9 | 17.1 | 18.6 | 16.4 | 21.2 | 14.3 | 10.9 | 7.9 |
| 2020 | 8.3 | 25.2 | 13.4 | 15.5 | 6.1 | 23.6 | 9.6 | 8.9 |

Source: systematized and built on the basis [17; 18].

Most agricultural producers grow sugar beet, sunflower and cereals and legumes, and the least - potatoes and bee families. The profitability of agricultural enterprises during 2016-2020 is shown in Table 1.

Analyzing Table 1, the highest profitability of operating activities is observed in 2016 - large enterprises (54.3%), however, within five years is declining and is 8.3%. Profitability of all activities of large enterprises in 2016 - 45.4%, and in 2020 - 6,!%. The level of profitability of agricultural enterprises operating in rural areas in Ukraine is shown in Figure 4.

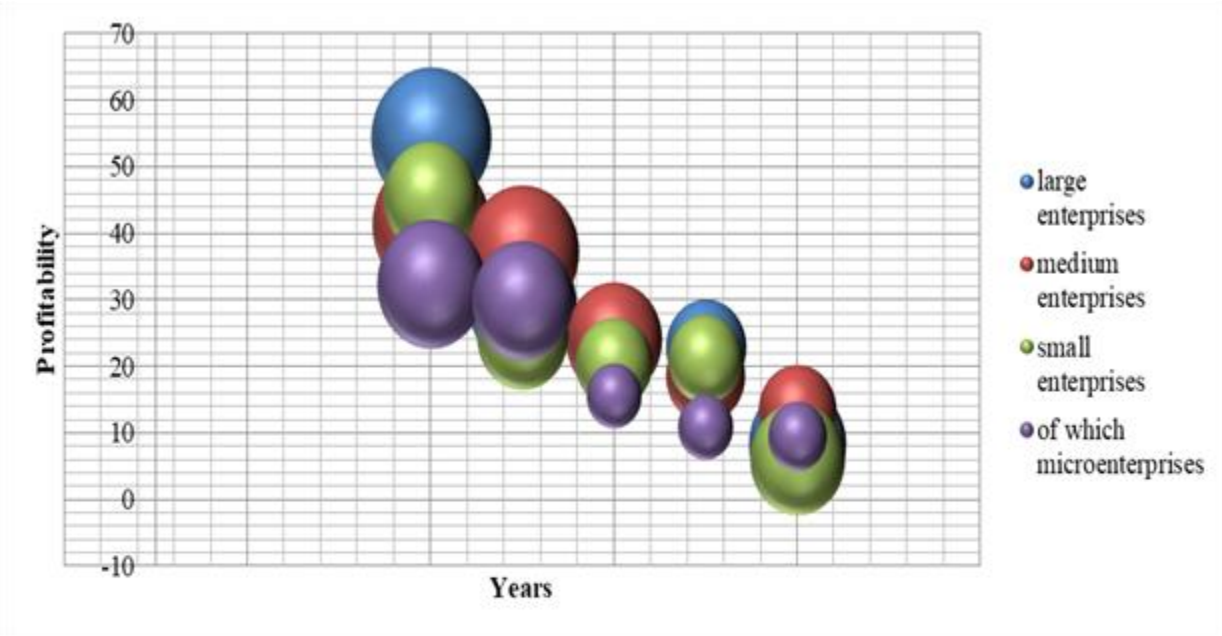


Fig. 4. The level of profitability of agricultural enterprises operating in rural areas in Ukraine
Source: own development.

A detailed analysis of the company's financial results, including profits, is very important for studying the features of corporate development in rural areas. We are building a multifactor model of profit (Y) dependence on the following factors: volume of sold products (X1), export of agricultural products (X2), Indices of agricultural production (in 2016 prices; in % to the previous year) (X3) (Table 2).

Table 2. Statistical data for building an economic-mathematical model

| Period | Net profit (billion UAH) (Y) | Volume of sold products (billion UAH) (X1) | Export of agricultural products (billion UAH) (X2) | Indices of agricultural production (in 2016 prices; in % to the previous year) (X3) |
|---|---|---|---|---|
| 2010 | 17.2 | 94.8 | 58.88 | 98.6 |
| 2011 | 25.2 | 119.1 | 78.88 | 120.2 |
| 2012 | 26.7 | 155.6 | 114.4 | 96.1 |
| 2013 | 14.9 | 153.9 | 174.2 | 113.6 |
| 2014 | 21.3 | 205.2 | 183.3 | 102.2 |
| 2015 | 101.8 | 349.7 | 193.7 | 95.2 |
| 2016 | 89.7 | 388.6 | 306.0 | 106.3 |
| 2017 | 68.2 | 437.4 | 338.0 | 97.8 |
| 2018 | 70.4 | 504.5 | 372.0 | 108.2 |
| 2019 | 92.8 | 537.6 | 439.3 | 101.4 |
| 2020 | 81.1 | 523.4 | 432.4 | 89.9 |

Source: systematized and built on the basis [17; 18].

The construction of the correlation-regression model according to the data in Table 2 was carried out with the help of Microsoft Excel spreadsheet tools, namely, the "Data Analysis" add-on.

Let's build a model:

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Table 3. Results regarding the correlation regression model and analysis of variance

| The result | |
|---|---|
| *Regression statistics* | |
| Plural R | 0.931 |
| R-square | 0.867 |
| Normalized R-square | 0.810 |
| Standard error | 14.945 |
| Observation | 11 |

| Analysis of variance | | | | | |
|---|---|---|---|---|---|
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 3 | 10,212.142 | 3,404.047 | 15.241 | 0.002 |
| Remainder | 7 | 1,563.427 | 223.347 | | |
| Together | 10 | 11,775.569 | | | |

| *Coefficients* | *Standard error* | *t-statistics* | *P-Value* | *Lower 95%* | *Upper 95%* | *Lower 95%* | *Upper 95%* |
|---|---|---|---|---|---|---|---|
| 4.310 | 64.964 | 0.066 | 0.949 | -149.306 | 157.926 | -149.306 | 157.926 |
| 0.441 | 0.116 | 3.808 | 0.007 | 0.167 | 0.715 | 0.167 | 0.715 |
| -0.349 | 0.142 | -2.466 | 0.043 | -0.684 | -0.014 | -0.684 | -0.014 |
| -0.025 | 0.591 | -0.042 | 0.967 | -1.423 | 1.373 | -1.423 | 1.373 |

Source: own development.

The coefficient of determination $R^2$ = 0.86 indicates that the change in the y indicator by 92% depends on the change in the available Xi factors.

We check the constructed model according to the Fisher test. The estimated value of the criterion $F_r$ = 15.24, while according to the tables of critical points $F_k$ =FRASPOBR(0.05;$k_1$;$k_2$)=4.63, where $k_1$= m; $k_2$=nm ($k_1$=3; $k_2$=10-3=7). Since Fr >Fk (15.24>4.63), then it can be assumed that the built model is adequate for the selected data. $y=0,44 \cdot x_1-0,34 \cdot x_2-0,02 \cdot x_3$.

Let's build a correlation matrix. Let's use the "correlation" tool for calculation in Table 4.

Table 4. Results regarding the coefficient of correlation between net profit, volume of sold products, export of agricultural products and index of agricultural production

| | Net profit (billion UAH) | Volume of sold products (billion UAH) | Export of agricultural products (billion UAH) | Indices of agricultural production (in 2016 prices; in % to the previous year) |
|---|---|---|---|---|
| Net profit (billion UAH) | 1 | | | |
| Volume of sold products (billion UAH) | 0.86 | 1.00 | | |
| Export of agricultural products (billion UAH) | 0.75 | 0.97 | 1.00 | |
| Indices of agricultural production (in 2016 prices; in % to the previous year) | -0.39 | -0.37 | -0.31 | 1 |

Source: own development.

According to the results of the calculations, it was determined that there is a strong correlation between the effective and factor characteristics. SWOT analysis of business development in rural areas is shown in Fig.5. The results of the SWOT analysis allow determining the directions of strategic actions of business development in rural areas based on taking into account the ratio of strengths (S) and weaknesses (W) of the internal environment of the Zhytomyr region and opportunities (O) and threats to the environment (T). The sustainable development strategy involves attracting investment resources to support the business sector. The strategy of informatization improves information services and provides for the creation of public organizations to protect the interests of entrepreneurs. The diversification strategy serves to cover different types of business activities to create new jobs. The sanitation strategy is based on closing unprofitable productions and increasing corporate social responsibility.

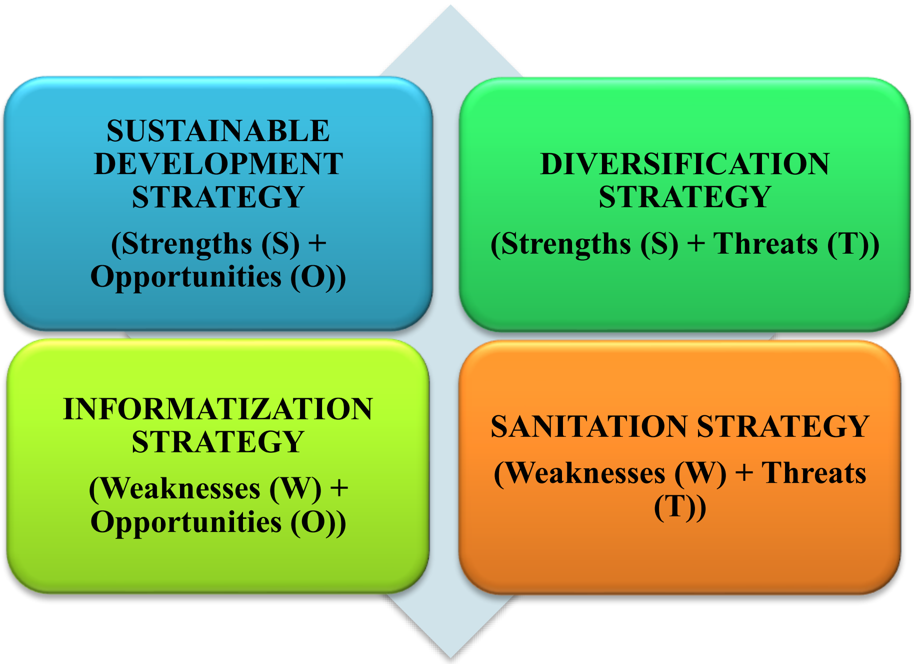


Fig. 5. SWOT-analysis of business development in rural areas
Source: own development.

Significant threats are the high cost of credit, imperfect taxation, and low purchasing power of the population. However, the possibilities of SWOT analysis allow attracting funds from the state budget and opportunities to enter foreign markets. It is believed that the community budget is stable when there are regular tax revenues from companies that conduct its business in a particular village, therefore, the countryside should always be investment-attractive. Stimulating factors are shown in Figure 6.

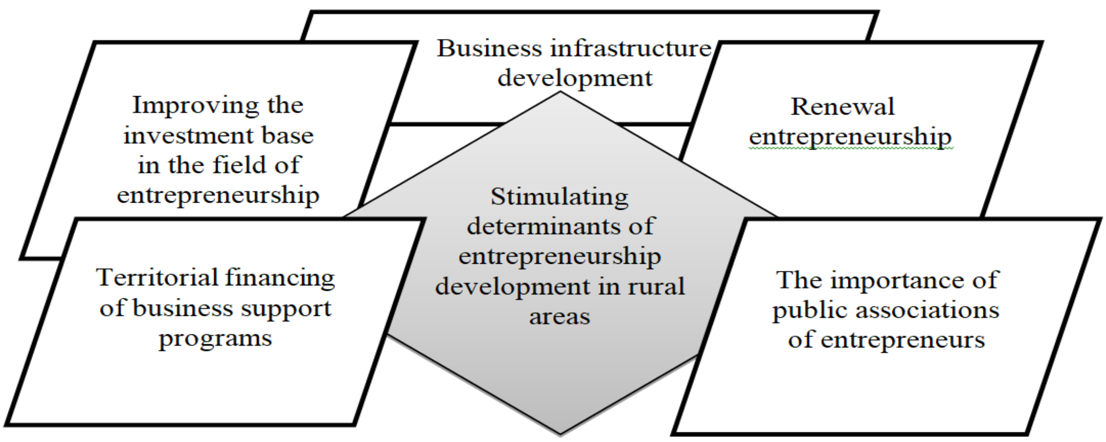


Fig. 6. Stimulating aspects of entrepreneurship in rural areas
Source: own development.

Today, innovation is a solid foundation for the development of the modern economy [2; 4], in particular, it concerns the problem of rural development and sustainable growth of agriculture [20]. At the same time, the introduction of innovations in the field of organization and management of agriculture is extremely important [19], public administration in rural areas, as well as in creating a favorable infrastructure for business and life in rural areas. The modern development of rural areas in Ukraine is based on innovation, creation, and use in a particular locality. The focus is on certain development priorities, allocation of state resources, opportunities, and infrastructure projects based on the country's development strategy. In this sense, rural areas do not differ from urban areas, as they must also offer businesses attractive conditions for starting and locating production, and for workers - an acceptable standard and quality of life [1]. To some extent, rural areas lost to urban areas in this competition, but it is important to identify and harness the potential competitive advantages of rural areas to place innovative businesses, for which there is a need for effective management of rural development [4], its optimization, adaptation to modern needs and conditions. The uniqueness of agricultural products is an important aspect, therefore it is necessary to take into account the specifics of rural areas when creating and implementing a new innovative product. Thus, the innovative development of rural areas in Ukraine is influenced by a set of factors, the main of which can be grouped into such groups [2; 16]:

- economic conditions;
- marketing conditions (demand for products produced in rural areas and for business activities in rural areas);
- search for alternative sources of income.

Innovations and new modern technologies are becoming key elements in the decision-making process for rural development:

1) technological changes take time;
2) adaptation and adoption of new innovative decisions often have a negative impact on production and the local economy at some stage;
3) management must understand that innovation is a source of regional development and technological change, so management decisions, models and tools used to stimulate rural development must also be innovative.

Improving the management of innovation and rural development involves changes in planning, employment, product promotion, communication between government and business, government and the public, and knowledge management. In this context, focus on working with active people to find common ideas for solving complex socio-economic problems, forming new perspectives, new paradigms and new ways of solving problems, ways to remove obstacles to creative thinking, finding examples. The analogy can help identify potential opportunities for rural development.

## CONCLUSIONS

Progressive management of rural development today must be innovative, focusing on taking full account of the relationship between macro-environmental changes in these areas and governance models, taking into account environmental, economic and social commitments. Optimizing the management of innovative development in rural areas of Ukraine may provide specific areas for development. The specific advantage does not contribute to the dynamic development of the village in economic, demographic and technological areas, only the integrity of the system will serve the effective development of territories

The article is proposed an optimized model of rural innovation and development management in Ukraine and the objects of management highlight key areas that affect rural innovation and development. The influence of certain directions of development and the introduction of innovations on rural development is characteristic. Emphasizes the promotion of infrastructure as an element of rural development, as well as the characteristics, models, methods and methodological techniques that form the general methodological basis for stimulating rural development based on infrastructural innovations.

At the same time, the success and scale of the implementation of innovative solutions in rural areas largely depend on the human factor, which involves a lot of work to identify, stimulate change, stimulate training and responsiveness.

Rural innovation organization for the active stratum of the rural population. With this in mind, successful management of innovations aimed at rural development are effective. Economic growth in the countryside is associated with new programs and projects, the implementation of which allows the community to increase competitiveness and and improve the economy of its environment. All this is possible thanks to the joint activities of the community and the active participation of rural residents in the formation of an innovative business model for the future.

Generally according to the research in modern conditions we can see that rural areas have an increased investment attractiveness, which is associated with the innovative development of e-commerce, digital economy and digitalization.

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# LOCAL GASTRONOMIC POINTS AS PART OF SUSTAINABLE AGRITOURISM AND YOUNG PEOPLE'S PERCEPTION OF IT. CASE STUDY, SIBIU COUNTY, ROMANIA

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***Abstract***

*The work highlights the importance of local gastronomic points (LGP) in the sustainable development of villages in the mountain area of Romania. The paper employed a quantitative and a qualitative analysis. In this paper there are presented the number of local gastronomic points established in the mountain area of Sibiu County, Romania, the number of local producers registered under the optional "mountain product" quality scheme and the number of tourist structures with accommodation function and their accommodation capacity, from the same localities. A case study of a local gastronomic point was carried out and an investigation was carried out regarding the knowledge of young people about local gastronomic points, respectively their role in the development of villages.*

***Key words*****:** *local gastronomic point, local food, food tourism, rural household, rural development, youth, Sibiu County, Romania*

## INTRODUCTION

The COVID-19 pandemic has highlighted the importance of a robust and resilient food system that works under all circumstances and is able to ensure access to a sufficient supply of affordable food for citizens. This pandemic has also made us extremely aware of the connection between health, ecosystems, supply chains, consumption patterns and the limits of the planet [5, 9, 33]. It is clear that we need to do much more to ensure the health of ourselves and the planet. The increasing frequency of droughts, floods, wildfires and new pests are a constant reminder that our food system is under threat and must become more sustainable and resilient [11, 15].
The "From Farm to Fork" strategy is a central element of the European Green Deal [13]. It addresses the challenges of sustainable food systems and emphasizes the inextricable links between healthy people, healthy societies and a healthy planet [12].
Shifting to a sustainable food system can bring environmental, social and health benefits, generate economic gains and ensure that overcoming the crisis is equivalent to embarking on a sustainable trajectory. It represents a comprehensive new approach to how Europeans value the sustainability of food systems. It is an opportunity to improve lifestyles, health and the environment. Creating an enabling food environment that facilitates healthy and sustainable food choices will benefit consumers' health and quality of life and reduce health-related costs for society. People are paying more attention to environmental, health, social and ethical issues and, more than ever, are looking for value in food [2, 14, 17, 36].
Despite the urbanization of societies, people want to feel closer to the food they eat. They

want fresh, less processed and sustainably sourced food, and calls to shorten supply chains have intensified in recent years. Consumers should be able to choose sustainable food products, and all actors in the food chain should see this as a responsibility and an opportunity [16, 26, 34].

Supporting and promoting local producers are elements of major importance for the sustainable development of an area/region [10, 32].

Rural development expresses the set of actions aimed at improving the quality of life in rural areas, based on sustainable economic growth, which maintains the natural landscape and material and spiritual culture [29] of the village communities [27].

Duirng the last years, gastronomy is percepted like one of the great opportunities to promote and strengthen special tourist destinations [22].

One of the targets provided by the Strategy for the development of the agri-food sector in Romania stipulates that by the end of 2030, the access of the rural population to basic services and infrastructure should be at least 80% of the levels of access in the urban environment registered at European.The development of non-agricultural activities in rural areas can generate additional income for farmers, reduce the rate of migration and create jobs [18].

In Romania, the establishment of local gastronomic points represents an opportunity for rural and gastronomic tourism enthusiasts. For this category of tourists, the authenticity of culinary experiences comes first, thus contributing to the development of the rural environment in a sustainable manner, by creating jobs, maintaining the cohesion of local communities and preserving culinary traditions, in harmony with nature.

Tourists are increasingly eager for unique experiences, direct contact with nature and the local community, culinary products obtained from a sustainable way, with an emphasis on animal welfare [21] and environmental protection [23].

Recently published works showed that local gastronomy and culinary practices as an integral part of the intangible human heritage, have major contributions in the sustainable development of an area [7], being a means of promoting local identity and a source of knowledge [6, 24].

In Romania, for the recognition of the activity of LGPs as a type of food service specific to small peasant households, various organizations have contributed, such as: Ivan Patzaichin Association – Mila 23, National Sanitary Veterinary and Food Safety Authority, National Agency of the Mountain Zoneand "Gastro Local" National Network [1, 3, 4].

"Gastro Local" is a national program started in 2019 and represents the interests of the owners of local gastronomic points from various counties such as: Brașov, Covasna, Sibiu and Tulcea.

The network supports producers with consultancy for authorization and promotion. At the same time, this is a way of creating a community synergy and a model of rural socialization around the gastronomic act. Through LGPs, visitors can serve a meal with traditional Romanian products at local households, in the area where they are spending their vacation, in a rustic atmosphere, but in compliance with the hygiene rules, imposed by law.

The development of rural mountain areas in Romania based on Gastro Local programs will lead both to an increase in the number of products from rural and mountain areas, registered as recipes or established products of the regions and the country, as well as to the expansion of the market and the competitiveness of traditional Romanian dishes [3].

The objectives of the work are:

1. Identification of the settlements in the mountain area of Sibiu County where local gastronomic points operate, the number of tourist accommodation structures in these rural areas and their accommodation capacity;
2. Realization of a case study regarding a local gastronomic point;
3. Providing an insight into young people's knowledge and perception of local gastronomic spots and the role they can play in the development of mountain villages.

## MATERIALS AND METHODS

A multiple methodology was used to develop the paper:

1. Specialized literature was consulted, and data was collected from the relevant public authorities in Romania regarding the operation of local gastronomic points, tourist structures with classified accommodation and producers registered under the "mountain product" quality scheme.
2. The research method also used to identify the localities in Sibiu County with opened LGPs and to described those activity was a qualitative one: an explanatory case study [8]. Such an approach to describing the activity of this type of public catering unit operating in a peasant household allows for an in-depth analysis of the farmer’s motivation and the attractiveness for tourists. The case study emphasizes the description and understanding of cases. Thus, a current phenomenon is investigated in a real context.
3. In order to analyse young people's perception of LGPs and their role, quantitative research was carried out. Thus, a questionnaire was developed in Google Forms that was distributed online between October 1st and October 25th, 2022. The questionnaire consisted of 19 items, and was structured in: socio-demographic data, preferences regarding culinary preparations consumed during vacations; the frequency of serving meals in public catering establishments; knowledge about the operation of LGPs (how to inform about LGPs; aspects related to the quality of services in LGPs; the budget allocated for serving meals in a LGP; the interest in purchasing local products from LGPs; the role of LGPs in rural development).

The responses were synthesized and statistically processed using Excel, v. 365 Microsoft Corporation, Redmond, WA, United States. To measure the intensity of agreement regarding some items, a 5-point Likert scale was used.

## RESULTS AND DISCUSSIONS

### The concept of Local Gastronomic Point

The National Rural Development Program 2014-2022 provides for the support of those agritourism activities that lead to responsible tourism, biodiversity conservation and income generation for village residents [19].

The development of rural communities and local tourism can also be achieved by establishing Local Gastronomic Points in Romanian villages. In them, you can eat dishes made from local products obtained according to traditional, authentic methods. Thus, the products from the peasant household, from the local community, are better valued, the meal is served in an authentic setting, and the village becomes a place for socialization and cultural communion.

The Local Gastronomic Point represents an effective way of capitalizing on products from the peasant household in family-type public catering units, considering the specifics of each touristic area/region with known gastronomic traditions. Unlike restaurants or guesthouses, local gastronomic points offer tourists the opportunity to benefit from traditional, local dishes, produced and served directly by family members in their own household, respecting legal hygiene requirements, without affecting the health of consumers [25].

These Local Gastronomic Points fit perfectly with the strategy of the European Union - "From the farm to the consumer". The essence of LGP is to bring the raw material from the household, from the local community and from the neighbouring communities to the tourists' plates. All products are very close to what local specificity means. The establishment of local gastronomic points in the communes in the mountain area represents another form of valorisation of the products of the mountain household through short food chains [31].

Starting in 2021, The Mountain Area Agency offers free courses and consultancy to all people interested in opening a local gastronomic point. According to the data provided by the agency, more than 2,000 course completion certificates were issued, and between 2018-2021, 171 LGP were established nationally [25] (Figure 1).

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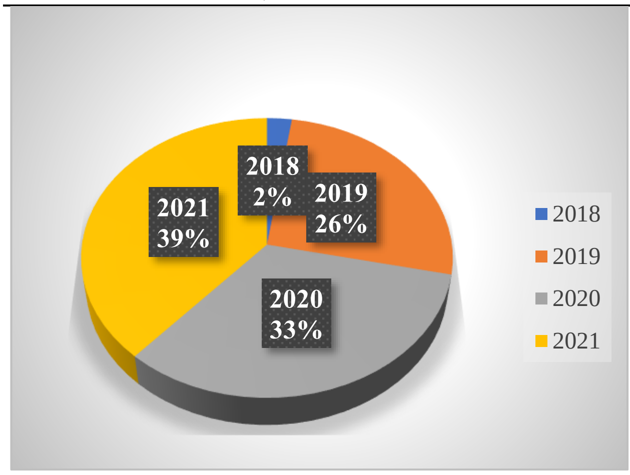


Fig. 1. Number of existing of LGP at the national level, between 2018-2021
Source: Own design.

Out of the total of 65 LGPs established at the national level in 2021, 48 operate in the mountain area, which demonstrates the interest of farmers in this area to capitalize on their products directly to tourists.

Table 1 Rural localities from Sibiu county with Local gastronomic points, touristic structures and local producers on ”Mountain product” quality schema

| Localities | No of LGP | No of producers on Mountain product schema | No of turistic structures | No of rooms | No of Places |
|---|---|---|---|---|---|
| Alămor | 1 | 0 | 0 | 0 | 0 |
| Alma Vii | 1 | 0 | 1 | 5 | 10 |
| Bradu | 2 | 2 | 2 | 13 | 27 |
| Cârțișoara | 1 | 1 | 38 | 423 | 990 |
| Cisnădioara | 2 | 2 | 15 | 102 | 217 |
| Colun | 1 | 0 | 1 | 2 | 4 |
| Cristian | 1 | 1 | 16 | 98 | 210 |
| Gura Râului | 2 | 0 | 32 | 223 | 480 |
| Jina | 1 | 1 | 3 | 14 | 26 |
| Nucet | 1 | 0 | 1 | 5 | 11 |
| Râu Sadului | 2 | 1 | 8 | 65 | 194 |
| Sadu | 2 | 5 | 7 | 48 | 101 |
| Șeica Mare | 1 | 0 | 1 | 7 | 14 |
| Total | 18 | 13 | 125 | 1,005 | 2,284 |

Source: own calculation based on ”Mountain product” platforme, and Ministry of Entrepreneurship and Tourism [1, 20].

**The Local Gastronomic Points in the mountain area of Sibiu County, the number of touristic structures in the localities where there are LGPs and their accommodation capacity**

In Sibiu County, 20 LGPs were established between 2018-2022, in localities such as: Gura Râului, Cisnădioara, Sadu, Cristian, Cârtisoara, Colun, Bradu, Alămor, Alma Vii, Șeica Mare, Râu Sadului, Nucet, Cisnădie, Jina and Mediaș [35].

The evolution of Local Gastronomic Points in Sibiu County between 2018 and 2022 is presented in Figure 2.

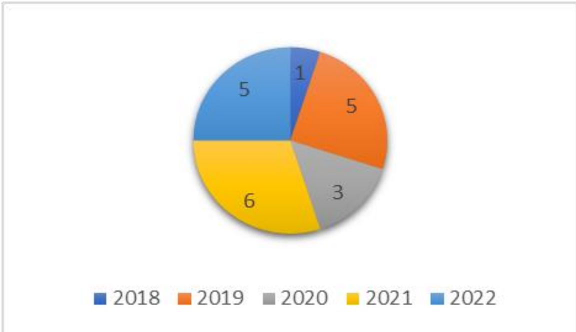


Fig. 2. The number of LGP established per year in Sibiu County between the years 2018-2021
Source: Own design.

In the rural localities of Sibiu County, 18 LGPs are registered as of 2022, out of the total of 20 existing in the entire county. In the same localities, 13 local producers are also registered who market their products under the "mountain product" quality scheme. They sell dairy products from cows, sheep and buffalo milk, fruits and vegetables, honey, canned vegetables and fruits. Table 1 shows the rural localities in Sibiu County where local gastronomic points operate, the number of classified tourist structures existing in these localities and their accommodation capacity.

It is noted that there is only one locality where, although there is a LGP, there are no classified tourist structures.

In the rural localities of Sibiu County where there are LGPs, 125 tourist structures are registered. In such localities where there is demand for rural tourism, LGPs have emerged as a necessity for tourists and an opportunity for farmers to directly capitalize on their produce and create short food supply chains. Most tourist structures operate in the localities of Cârtisoara (38) and Gura Râului (32).

**Case study – The local gastronomic point "Cămara Chivuței"**

The Local Gastronomic Point "Cămara Chivuței" in Sadu commune was established at the end of 2020, as a necessity to satisfy the increasing demand of tourists visiting the area, for local products and gastronomy.During the Covid 19 pandemic, there was a growing demand for tourist services in the countryside, where tourists felt safer compared to large urban agglomerations. For the Veștemean family, the decision to establish a Local Gastronomic Point came naturally, as a way of diversifying the production activity of canned fruit and vegetables for which it holds sanitary-veterinary and food safety registration.In this way, the opportunity was created to make better use of own products registered under the "mountain product" quality scheme, through the preparations specific to the area, offered to tourists who cross its threshold, eager for an authentic gastronomic experience [25].

Photo 1. Entrance to LGP ”Cămara Chivuței”, Sadu village, Sibiu County, Romania [28]
Source: Original (2021).

The analyzed LGP is an example of good practice by which both own products and those of local producers of dairy, meat, bakery or honey products are highlighted and a proof of the fact that the gastronomic experience offered constitutes a point of tourist attraction in the area and better utilization of local resources.

The owner of the LGP declared that she is a chef by profession, she established this family food unit out of the desire to capitalize on her own raw material and to respond to the requests of tourists staying in tourist structures in the area where food services are not offered.

Photos 1-3 show aspects of the local gastronomic point "Cămara Chivuței" Sadu Village, Sibiu County.

In addition to the services of offering meals to tourists, the owners have numerous requests to sell home-made preserves, both from tourists and from Romanians in the country or those settled abroad.


Photo 2. General aspects from the local gastronomic point ”Cămara Chivuței”, Sadu Village, Sibiu County, Romania [28]
Source: Original (2021).

To promote the services and products offered, the Veștemean family has a page on social networks and takes phone orders, with direct delivery of products to the consumer's door or via courier services to customers in the country.

By directly exploiting the fresh products obtained in the households of the mountain area and offering fresh dishes, cooked slowly, according to traditional recipes, the local gastronomic points contribute to the development of sustainable tourism.

Photo 3. The cellar of the local gastronomic point ”Cămara Chivuției”, Sadu Village, Sibiu County, Romania [28]
Source: Original (2022).

Photo 4. Tasting products at the local gastronomic point ”Cămara Chivuției”, Sadu Village, Sibiu County, Romania [28]
Source: Original (2022).

The success of the business of rural entrepreneurs depends on their ecological attitude and willingness to integrate sustainability into their current business, as well as their willingness to share their traditional knowledge and lifestyle with tourists [30].

**Young people's perception of local gastronomic points and their role in the sustainable development of villages in the mountain area**

The questionnaire was completed by 103 people. The presentation of the socio-demographic data of the respondents is presented in Table 2. The average age of the respondents is 24.5 years.75.73% of respondents are women, 52.4% live in rural areas. A share of 88.34% of the respondents' families have an average monthly household income below 7,500 lei, and in 79.61% of the cases, the families are made up of 2 to 4 people.

Table 2. Data on respondents

| Specification | | Frequency | % |
|---|---|---|---|
| Gender | Male | 25 | 24.27 |
| | Female | 78 | 75.73 |
| | Total | 103 | 100 |
| Domicile | Urban | 49 | 47.57 |
| | Rural | 54 | 52.43 |
| | Total | 103 | 100 |
| Age (years) | 18-30 | 91 | 88.35 |
| | 31-40 | 4 | 3.88 |
| | Above 40 | 8 | 7.77 |
| | Total | 103 | 100 |
| Family income | Below 2,500 lei | 23 | 22.33 |
| | 2,501-5,000 | 43 | 41.74 |
| | 5,001-7,500 | 25 | 24.27 |
| | 7,501-10,000 | 6 | 5.83 |
| | Above 10,001 | 6 | 5.83 |
| | Total | 103 | 100 |
| Persons in household | 1 | 4 | 3.88 |
| | 2-4 | 82 | 79.61 |
| | 5-6 | 12 | 11.65 |
| | Above 6 | 5 | 4.86 |
| | Total | 103 | |

Source: own calculation.

**The type of preferred cuisine, the habit of serving meals outside the household**

The respondents expressed their preferences regarding the culinary preparations consumed during the holidays spent in the rural environment as follows: 67% traditional, locally specific dishes, 18.4% international cuisine dishes, 9.7% fast food, respectively, 4.9% others. More than half (52.4 %) of the respondents stated that they serve the meal occasionally in a public catering establishment, while 25.2 % usually serve the meal outside the household often or very often.

Only 38.8% of young people said that they used to participate in gastronomic events such as culinary festivals, fairs or brunches.

**Knowledge of local gastronomic points and the perception of their role in the development of villages**

76.2% of the respondents believe that they know what a local gastronomic point is, although only 32% correctly identified the 12-seat capacity of such a public catering establishment.

At the same time, 61.2% of young people stated that they had served a meal at a local gastronomic point in Sibiu County. As expected, for young people the most important source of information on LGPs is relatives/friends (41.8%), followed by social networks (22.8%).

In the opinion of young people, the most important aspects on which the success of a LGP activity depends are: its appearance (82.5% considering it to be important or very important), the price of the dishes (85.4% of the respondents believe that it decisively influences the decision to serve the meal in a LGP) and the attitude of the staff (97.1 % of respondents stated that it influences their decision to serve a meal in a LGP).

The frequency of the answers received regarding the importance of the general appearance of a LGP for the success of the activity is shown in Figure 3. The average value of the answers obtained was 4.117, which shows that for young people the traditional appearance, specific to the area, increases the attractiveness of the LGP.

The willingness to pay for a meal at a local gastronomic point is between 51 and 100 lei/person in the case of 56.3% of the answers, under 50 lei/person in the case of 20.4% of the answers and over 101 lei/person in the case of 23.3% of the respondents. (Exchange rate: 1 Euro = 4.9134 lei)

The importance that young people consider LGPs have is given by the fact that they are perceived as an additional source of income for farmers (92.2%) and contribute to the sustainable development of rural tourism and villages (96.1% ).

There is a need for better promotion of the activity of local gastronomic points, especially among young tourists. O mai bună promovare a conceptului de punct gastronomic local conduce la conservarea și promovarea produselor locale, gastronomiei locale, susține agricultura tradițională și cultura locală.

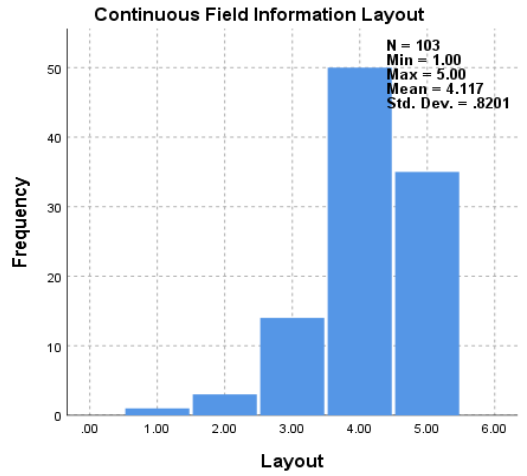


Fig. 3. The importance of the LGP aspect in the view of young people
Source: own design.

When leaving local gastronomic points, 77.7% of those surveyed want to buy products from farmers. These products are: bread and bakery products (70.87%), fresh fruit and vegetables (68.93%), meat preparations (67.96%), milk preparations (62.13%), jam, syrup and honey (61.16%), cooked food (54.36%), preserves and pickles (33%) and eggs (32.03%).

## CONCLUSIONS

The diversification of agricultural activity in a rural household by establishing Local Gastronomic Points represents a new opportunity, worthy of consideration by the inhabitants of rural areas.

The activity carried out by local gastronomic points contributes to the development of the rural environment in a sustainable manner by creating jobs, maintaining the cohesion of local communities and preserving culinary traditions, in harmony with nature. This creates a sustainable link between agriculture and tourism.

Local gastronomic traditions and local culinary preparations contribute to completing the image of a rural tourist destination. Gastronomic tourism highlights local and national identity, which can be amplified by organizing gastronomic events in the countryside.

The Local Gastronomic Points, on the one hand, represent an essential factor in attracting tourists to the area, and on the other hand, they can be found among the solutions to many of the local development and environmental problems.

Tourists who dine at a local gastronomic point want to have a local gastronomic experience and get to know the lifestyle of the farmers who carry out such an activity. In this way they can know the local and regional cultural diversity.

We believe that in the future the families of farmers in the mountain area who have authorized a local gastronomic point should be supported to diversify their activity and obtain the right to accommodate tourists in 3-5 rooms. In general, in the houses of farmers in the mountain area there is surplus accommodation space that could be introduced into the agritouristic circuit. For such an accommodation activity, complementary to the agricultural activity of the mountain household and that of providing public food services at the local gastronomic point, classification should not be necessary.

A better promotion of the concept of a local gastronomic point leads to the preservation and promotion of local products, local gastronomy, supports traditional agriculture, a certain lifestyle and local culture.

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# DIGITALIZATION OF AGRICULTURE – A BIBLIOMETRIC ANALYSIS

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***Abstract***

*This study aims to complete the previous studies and to create an overview of the interest given to the field regarding the digitization of agriculture. The analysis was carried out on a sample of 604 scientific documents published on the Web of Science (WoS), using the VOSviewer software. The study first analyzes the annual trend of publications, the annual trend of article citations as well as the trend of keywords and co-authorship by country. In many studies, the process of digitalization of agriculture is discussed in which various technologies capable of facing the current challenges regarding the agri-food sector are proposed. However, bibliometric studies on the digitization of agriculture are few. The results emphasize the methodological approach, obtaining maps with the terms that appear frequently in the analyzed studies, being grouped into 6 clusters, two of which are representative. The yellow cluster consists of terms related to digitization, climate change, and machine learning while the red cluster consists of terms related to agriculture, performance, management, and big data. Out of the total of 604 published documents, Romania has a percentage of 26% of published articles, being the leader in the ranking.*

***Key words***: *digitalization of agriculture, Romania, smart agriculture*

## INTRODUCTION

The phenomenon of globalization has a direct impact on agriculture, forcing farmers to use new agricultural models instead of traditional ones, the reason being the implementation of sustainability in the field [3].
Digitization represents a new direction to increase the efficiency of the agro-industrial structure and the sustainable development of the agricultural sector. Technological innovation in the agricultural field is considered to be a solution for agro-industrial countries, agricultural technologies based on computer systems, automation, and robotization, used on a large scale accelerate the increase in productivity and profitability of agricultural holdings [11].
The digitalization of agriculture has as its main objective the implementation of IT technologies [15] and innovations in agricultural production, the protection of the environment, as well as ensuring the food security of people and animals. The sustainable development of agriculture through its digitization primarily involves the development and use of new management models that are based on information technologies and that ensure the increase of yield in agricultural holdings, the preservation of biodiversity by reducing the negative impact on the environment, thus ensuring a level sustainable production and profit [4].
The digitization process consists of improving production and transport systems, improving the implementation of support measures in the sector, and optimizing the use of resources so that the continuous flow of products can be ensured [6].
Currently, the digitization of agriculture can represent a viable solution for solving the problem of the lack of labor force, because in agriculture this lack is acutely felt, and the rural population is on the decline. Thus, the implementation of new management concepts, automation, sensors, and robots in agricultural production processes will reduce the need for labor, while at the same time increasing agricultural productivity and efficiency [16].
According to the European Commission, the most relevant technologies and techniques to be exploited are the following: satellite technologies for image delivery, the use of agricultural robots, as well as the use of unmanned agricultural vehicles/machines (UAVs) to collect conclusive/demonstrative

data on the real situation from agricultural holdings [6].

## MATERIALS AND METHODS

Bibliometrics is considered a method of quantitative measurement of scientific publications in a certain field and appeared in the scientific world as early as 1969, in a documentary note by Alan Pritchard. The bibliometric analysis includes various mathematical and statistical methods for evaluating bibliometric data [7]. Through the use of this technique, we sought to understand the interrelationships between the number of documents published in the field of digitalization of agriculture, an existing research topic, the frequency of citation of articles, and the interest given to a specific topic/research area by country. Through the VOSviewer software, the data were presented graphically, through category maps. The data were collected from the Web of Science database, and a query was made for the term "Digitalization of Agriculture", resulting in a total of 604 documents.

## RESULTS AND DISCUSSIONS

Figure 1 shows the annual publication trend from 1987 to 2022 with a total number of published papers of 604, excluding the inactive publication years of 19987-1992, and 1992-1997.


Fig. 1. Annual trend of publications of bibliometric papers from 1987 to 2022.
Source: Own representation based on data provided by Web of Science.

The data reached its maximum level in the year 2022 with 126 documents, of which the majority of articles were published at the Multidisciplinary Digital Publishing Institute (MDPI) and Elsevier (Fig. 1).
This reflects the growing interest in research related to the digitization of agriculture as well as the progress made in the context of the implementation of digital technologies, even if the pace is still low compared to other fields [5]. Digital agriculture (agriculture 4.0)[1] provides farmers with a complex set of tools for food production challenges associated with farm productivity, environmental impact, crop losses, and sustainability [12].
Publications cannot be relevant if the documents are not cited in turn by other studies. Thus, the total annual citations are represented in Figure 3. During the period 1987-2006, there was no observable trend in terms of citations. In the following period, the total number of citations began to increase, reaching in the last period a total number of 925 citations (2022) (Fig. 2).
Figure 3 shows the links between keywords (nodes), providing an overview of the main research topics and trends. Those nodes represent highly cited publications or highly prolific researchers, who may have more connections than their less popular counterparts.
In bibliometric network analysis, a normalization is usually performed for these differences between nodes. The lines between the nodes represent the connections between these keywords. After the network has been normalized, the next step is to position the nodes in the network in a two-dimensional space in such a way that strong nodes are connected, while weakly connected nodes are located far from each other.
For this purpose, VOSviewer uses the VOS mapping technique, where VOS stands for "similarity visualization" (Fig. 3).
The yellow cluster consists of topics related to digitization, climate change, and machine learning. It is believed that future climate change will further amplify already existing risks and even create new ones, making the measures taken crucial for managing new environmental challenges [14].

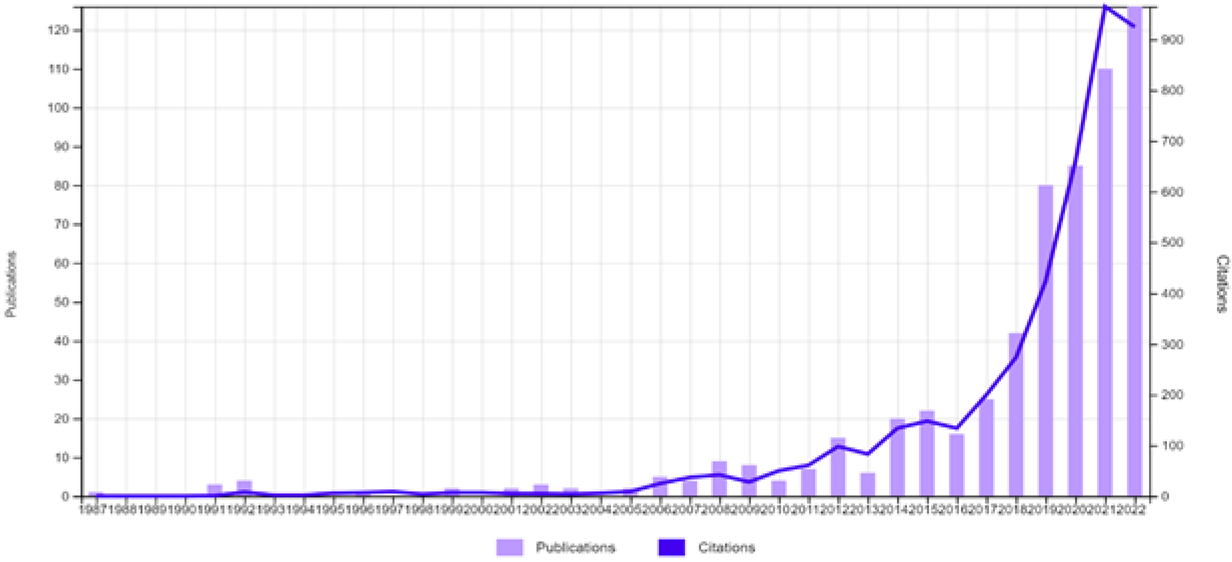


Fig. 2. Annual trend of bibliometric article citations
Source: Web of Science.

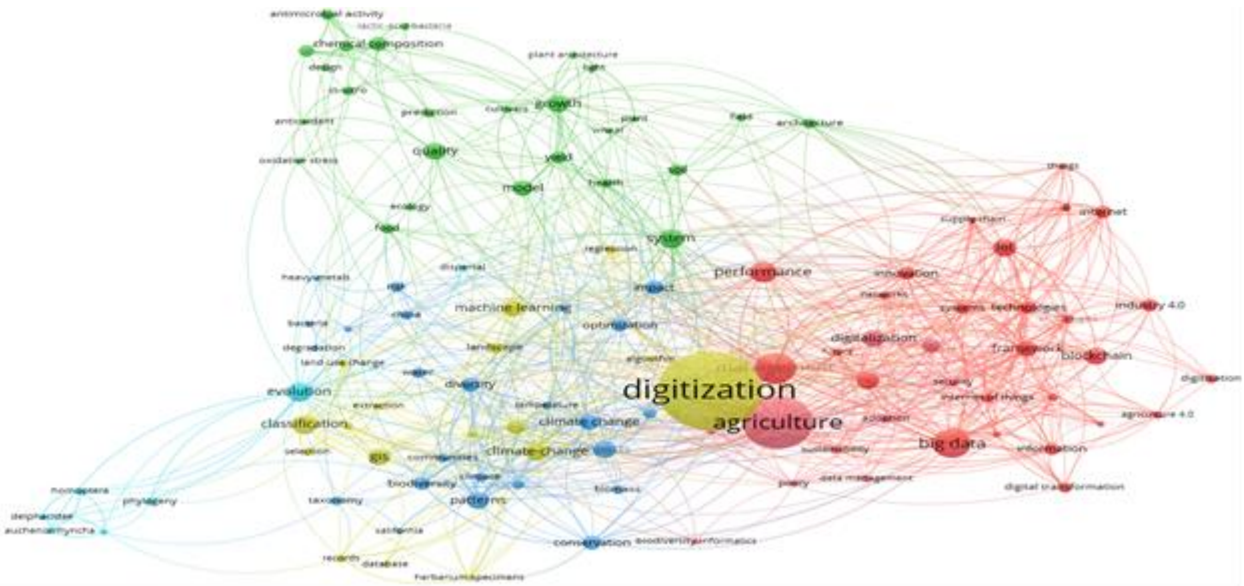


Fig. 3. Network view of the keyword "digitalization of agriculture".
Source: Own representation based on data provided by Web of Science.

The application of digital technology in agriculture was, is, and will be an essential and primary element to promote, generate data and analyze it advanced, allowing all farmers to make intelligent decisions in agriculture, but also to benefit from the economic use of all inputs and labor. Together with the connectivity between mobile devices and other platforms, the digitization of agriculture will generate a high volume of data and information that will serve as the basis for future decision-making. It is also argued that the digitization of agriculture can bring substantial improvements worldwide, in terms of increasing the productivity and efficiency of agricultural systems, adapting to climate change, but also reducing food waste, and making the use of natural resources more efficient in a sustainable way [5]. In this context of climate change, digitization is an important management tool to prevent agriculture develop a protection plan to combat pests and maintain soil quality [9]. In addition to the ability to intensify the work process, the use of digital technologies helps to improve vulnerabilities related to seasonality. Following this logic, German farmers consider the use of digital technologies in the long term as a tool to reduce farm costs, including labor costs in the horticultural sector [2].

The red cluster indicates topics related to agriculture, performance, management, and big data. Big data in agriculture gives all farmers the ability to view detailed data on specific elements such as rainfall, water cycles, soil fertilizer requirements, and more. By using this technology, farmers can make smart decisions to plant the best crops to get the best return [13]. Recent studies have demonstrated that big data will have a substantial impact on the development and application of digital technologies in agriculture, even if this field is still in its infancy [10]. The high potential of digital applications for agriculture is generating excitement about the future of agriculture. Some people in the field claim that the intelligence offered through these digital tools is a way to solve the still persistent problems in agriculture [8].

604 articles on the digitization of agriculture from over 100 countries were retrieved. Table 1 shows a list of the top 10 countries with the largest number of published documents, representing 96.19% of all publications. As of 2022, Romania had the most articles published in this field, followed by China and Germany. In addition to the global dominance in research related to the digitization of agriculture, Romania continues to lead the ranking for the last 5 years, as a result of the involvement of the European Union in balancing the agricultural sector by encouraging farmers to use and apply digital technologies (Table 1).

Table 1. Top 10 countries with the highest number of publications

| Country | Documents | Citations |
|---|---|---|
| Romania | 157 | 415 |
| USA | 98 | 1,404 |
| China | 85 | 641 |
| Germany | 59 | 560 |
| India | 43 | 285 |
| Italy | 34 | 492 |
| Russia | 28 | 77 |
| France | 27 | 881 |
| Czech Republic | 25 | 454 |
| Spain | 25 | 357 |

Source: Web of Science.

Figure 4 represents bibliographic cooperation where countries are used as the unit of analysis.

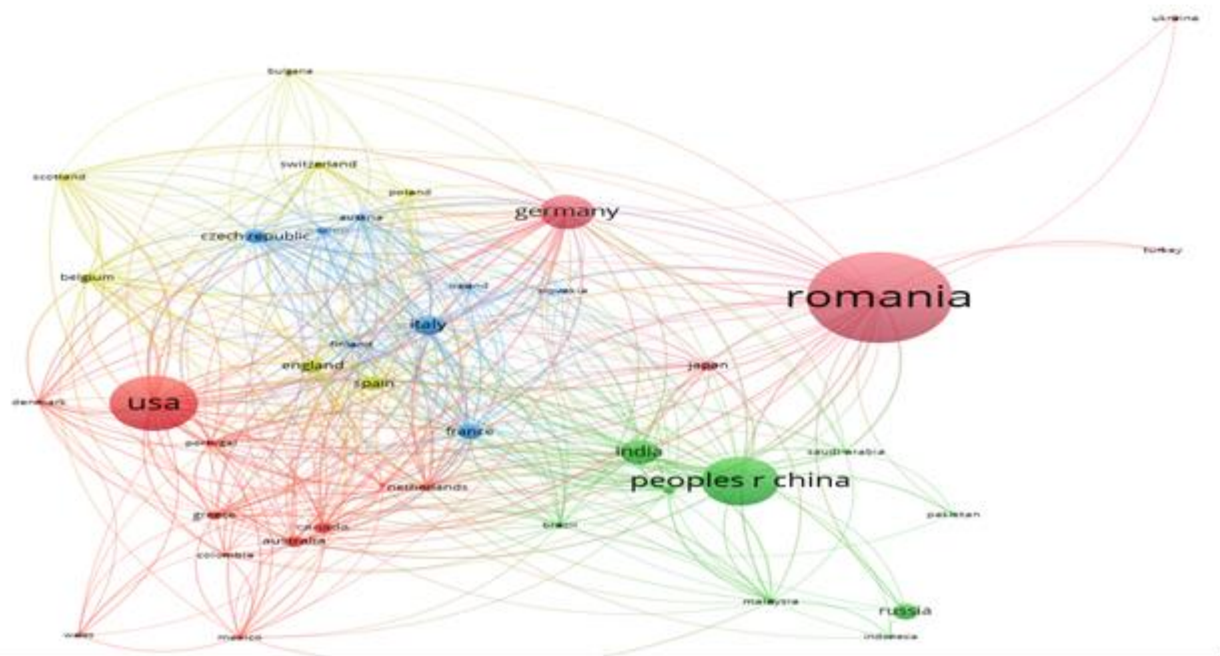


Fig. 4. The link between co-author countries on the concept of "digitalization of agriculture”
Source: Own representation based on data provided by Web of Science.

The study established certain limitations of the model, for example, a minimum number of 5 elements were required for a country to appear on the map. According to figure 4, it can be seen that Romania has research collaborations, especially with researchers from Germany and the USA, but also with researchers from Japan, Turkey,and Australia (Fig. 4).

## CONCLUSIONS

The purpose of this study was to complement previous studies, provide an overview of the field's interest in the digitization of agriculture, and extend the current literature for future research. Based on the bibliometric technique, the most relevant existing themes in the current research were identified, observing promising directions for future approaches.

When performing the analysis, 604 documents were selected to understand the relationships between the digitization of agriculture and the interest given to this field of research depending on the country. As a result, the analysis fulfilled its objective, by identifying numerous publications, from which several meaningful perspectives can be derived.

First of all, the number of documents related to the "digitalization of agriculture" increased substantially in the period 2017-2022, most of them being published in the Multidisciplinary Digital Publishing Institute (MDPI) and Elsevier, being some of the most important journals that contribute to the literature on digitization agriculture. Regarding the global impact, it was found that in the top 10 with the highest number of publications in this field, Romania is the leader in the ranking with a weight of 26% of the articles (157 documents).

By grouping the keywords resulting from the query of the database, 2 main topics from the specialized literature were noted: Digitization and Agriculture interconnected by various terms such as big data, management, climate change, etc. An alarming threat to agriculture is related to climate change that should be examined in such a way that practices and technologies that reduce the side effects are adopted.

Finally, the subject of the digitalization of agriculture needs special attention mainly in terms of developing objective metrics to demonstrate that the application of the technology can meet all the requirements related to maintaining the sustainability of the agricultural industry.

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# IMPLICATIONS OF TURNOVER ON THE PROFITABILITY OF MEDIUM-SIZED FARMS IN ROMANIA

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***Abstract***

*The main economic objective of farms in Romania is to maximize turnover, this indicator being identified as the main source of profit growth. This paper analyses the turnover of a medium-sized vegetal farm, which is classified as a micro-enterprise for tax purposes. The data were collected from the enterprise accounting regarding the balance sheet and profit and loss account and rate method was used to assess the impact of turnover on various financial indicators. To increase turnover, the medium-sized vegetal farm acts in accordance with its own needs for development and expansion on the market, the conclusion being that an advantageous position on the market is interdependent with an increased turnover and therefore with greater profitability.*

***Key words*****:** *turnover, profit, agricultural holding, Romania*

## INTRODUCTION

Turnover is an indicator that shows the total sales made by a company over a period of time, and is essential for vegetal farms in Romania, as it shows the value of the total quantities of agricultural products sold, works or services rendered, indicating the size of the carried out activity. But turnover gives an indication of the amount of sales resulting from the sale of the farm's products and goods during a financial year, and by aggregating them the company can make a profit, after deducting all the expenses incurred in making them [2]. In order to assess the size of the economic activity of the medium-sized vegetal farm and to avoid fluctuations over time, it is necessary to ensure the resources to achieve the proposed objectives. The evolution of turnover must take into account the absolute value and the growth of prices in the economy, by determining a real level, measured in comparable prices or constant prices. Turnover, from an accounting point of view [11], is an indicator that establishes the classification of entities by size classes, according to which the set of financial statements to be filed annually (Table 1).

Table 1. Classification of entities by size class

| Crt. No. | Indicator | **Micro-entities:** companies that, at the balance sheet date, meet at least two criteria: | **Small entities:** Companies that, at the balance sheet date, do not qualify as micro-entities and do not exceed the limits of two criteria: | **Medium and large entities:** Companies exceeding the limits of at least two criteria: |
|---|---|---|---|---|
| 1. | Total assets | 1,500,000 lei | 17,500,000 lei | 17,500,000 lei |
| 2. | Net turnover | 3,000,000 lei | 35,000,000 lei | 35,000,000 lei |
| 3. | Average number of employees | 10 | 50 | 50 |

Source: [11].
Note: Exchange rate Euro/Lei according to the national Bank of Romania is Euro 1 = Lei 4.95 in November 2022.

Small and medium-sized enterprises are considered the backbone of economic activity in most countries [3]. From a tax point of view [6], turnover is an essential criterion for the classification of a limited liability company in the sphere of micro-enterprises or those liable to corporate tax [17].

Table 2. Classification of companies and tax according to turnover

| Crt. No. | Specification | Ltd – Micro-enterprise | | | Ltd– Profit tax | |
|---|---|---|---|---|---|---|
| | | Year 2022 | | Year 2023 | Year 2022 | Year 2023 |
| | | Turnover <1,000,000 Euro | | Turnover <500,000 Euro | Turnover >1,000,000 Euro | No ceiling, option from establishment |
| | | 1 or more full time employees | Without employees | Mandatory minimum 1 full-time employee | Mandatory minimum 1 full-time employee | |
| 1. | Income/profit tax | 1% Income tax | 3% Income tax | 1% Income tax | 16% Profit tax | |
| 2. | Dividend tax | 5% | | 8% | 5% | 8% |

Source: [6].

The system of turnover indicators refers to the determination of marginal, average, critical and total turnover. Turnover is used to analyse the performance of economic entities on the basis of the volume of sales achieved and the amount of receipts, thus determining the market dominance of the entity concerned. Turnover is an indicator on the basis of which economic development planning can be carried out at farm level, and is the benchmark showing how farms are developing. Due to the complexity and importance of turnover, this indicator can be analysed from several points of view, so that the analysis can best capture the impact it has on the overall activity of agricultural holdings [18]. The financial analysis in medium-sized vegetable farms highlights the importance of increasing income, maintaining production costs at an optimal level, in order to ensure a balanced ratio between capital and debts, between receivables and cash flow, a higher turnover and implicitly higher profit [12]. The results of the analysis of turnover, by relating it to the production achieved and comparing it with previous periods, by determining its share in total income, show the trends in income realisation, the analysis of which will highlight aspects that can be translated into specific objectives. The purpose of the analysis of turnover is to provide a suggestive picture of the management strategy adopted by the agricultural holding and to establish its market position, differentiated by market segments with different added value [8]. Analysis of the dynamics and structure of turnover highlights the flexibility of the market in which the farm operates, with the associated risks, which can be counteracted by diversification. Correction at the level of the whole activity, by observing the structure of the turnover and its change, refers to the evolution of the farm during the analysis period - upwards, downwards or stationary - and according to this, important management strategies can be consolidated. Each factor or component that has a significant influence on turnover, directly or indirectly, needs to be analysed and negative deviations require correction. As internal factors in the achievement of turnover, we mention the labour force that directly participates in the production process, highlighting finally the labour productivity in direct correlation with the evolution of turnover. In order to increase productivity by reducing the input of labor in agriculture, a calculation is made of the potential of the active labor force, age, level of education, applied technical and technological equipment, but also of the farm structure in terms of size and profile [13]. Another important factor at farm level is the selling price at which agricultural production is sold. Romanian farmers capitalized on the funding received from the EU to build grain warehouses useful for achieving an optimal capitalization price, because agricultural products are sold at the time of harvest. At the same time, subsidies often make the difference between profit and loss [8]. But it is not to be neglected in the analysis, the productive capacity of the farm, the soil type [5], the annual agro-meteorological and climatic factors, the technology involved [10], the level of fertilisation and use of plant protection products, crop irrigation, which ultimately influence the annual agricultural production achieved and therefore the level of turnover. In the category of external factors with a direct influence on turnover, we mention demand, as the primary factor in achieving the level of turnover at farm level, without which there is no income, regardless of production capacity, applied technology, material, human or financial resources involved. It is opportune to implement a mechanism for managing land resources in agriculture with the help of digital technologies [4], because technical innovations that respond to the challenges of climate change have a major influence on turnover. Intangible assets in the form of property rights in the use of land, water and other natural resources, intellectual property rights, inventions and know-how have an important role in increasing turnover [16].

Also, in the category of external factors that can influence turnover, we mention competition, changes in customer needs brought about by changes in income, socio-professional, demographic and legislative changes.

All these internal or external factors, which directly or indirectly influence turnover, have a major influence on the activity of the medium-sized agricultural holding analysed and represent standard management parameters.

Agricultural activity is also an important component of the bioeconomy sector that leads to obtaining an innovative agricultural production and resorts to the conversion of biological resources [19].

In this context, the paper aimed to analyze the turnover of a medium-sized vegetal farm, which is classified as a micro-enterprise for tax purposes, and in what measure it influences the profitability.

## MATERIALS AND METHODS

The paper highlights how medium-sized (500-1,000 ha) arable farms in Romania secure their income according to their own object of activity, mainly from sales of agricultural products and goods and supplemented by income from works and services rendered, stored production or income related to production costs in progress, supplemented by income from operating subsidies.

In order to be able to capture the way in which this income is generated, the analysis focuses on turnover in an agricultural company operating 600 ha, and in order to make this analysis relevant, it was necessary to determine specific indicators such as: the development and structure of turnover, the rotation period of receivables, debts to suppliers, stocks, the rate of rotation of current assets, the rate of profit margin before interest, tax, depreciation and amortisation, the rate of net operating margin, the rate of gross self-financing margin, the rate of net margin.

The results were presented in tabular and graphical form.

The technological and economic-financial information was provided by the manager of the medium-sized vegetal farm and formed the basis of the work together with an extensive bibliographical base.

## RESULTS AND DISCUSSIONS

At the level of the agricultural company analysed, the existence of crop cultivation according to the main object of activity (Classification of Activities in the National Economy no. 0111 Growing of cereals - excluding leguminous plants and oil seed producing plants) is noted [9, 17].

The crop structure is shown in the following graph and highlights the existence of crops such as autumn wheat, rapeseed, maize, lucerne and soya, unevenly cultivated during the analysis period, predominating with maize

(35%-46% of the area), wheat (17%-34% of the area) and rapeseed (22-31% of the area) as shown in Figure 1.

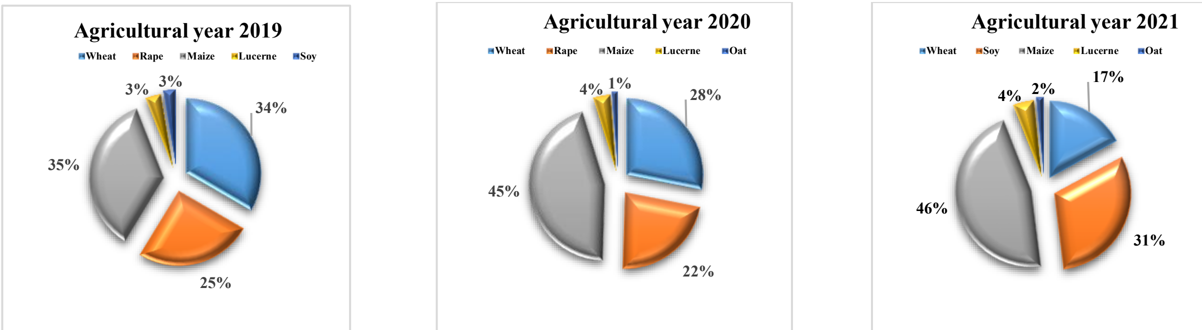


Fig. 1. Crop structure on medium-sized crop farm by agricultural year
Source: Own processing based on information provided by medium-sized vegetal farm.

Turnover is the most synthetic indicator that shows the income from sales and receipts of the medium-sized crop farm. Thus, for the crops highlighted above, this agricultural enterprise obtained the following yields as shown in Figure 2. It should be noted that in 2020 the lowest yields were recorded due to crop calamity caused by unfavourable agro-meteorological phenomena (frost, lack of snow), while in 2021 the highest yields were recorded: 14,309 kg/ha for maize, 7,668 kg/ha for barley, 7,066 kg/ha for wheat, 4,154 kg/ha for soya and 2,295 kg/ha for oats (Figure 2).

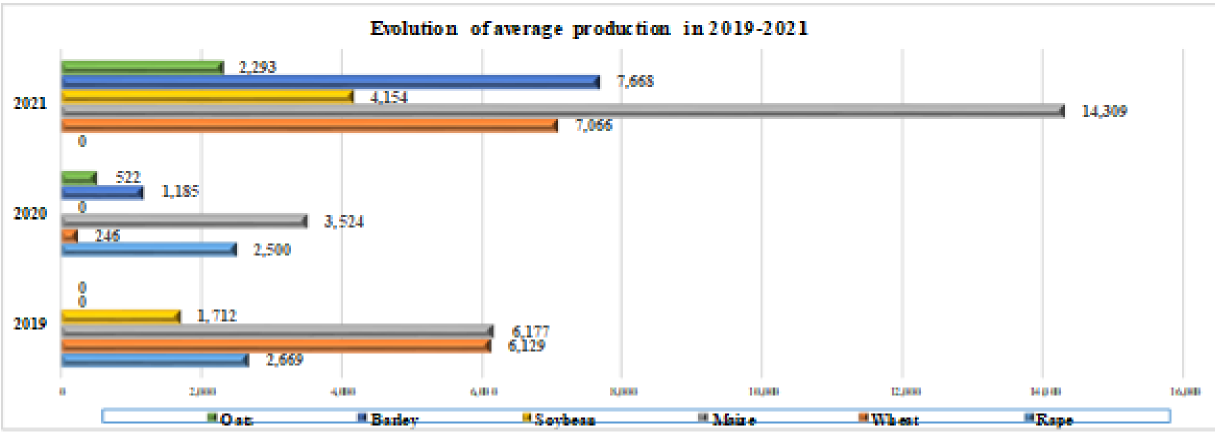


Fig. 2. Average yields of different crops in the medium-sized crop farm
Source: Own processing based on information provided by the medium-sized agricultural plant farm

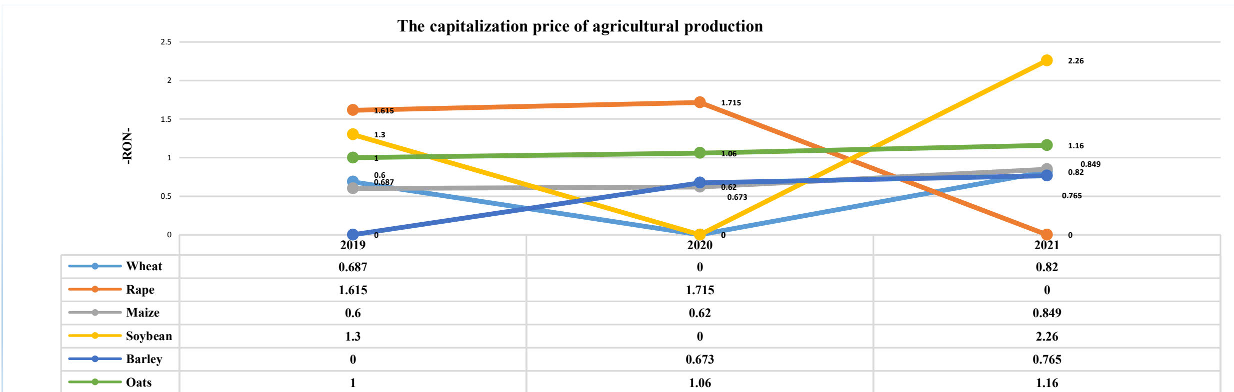


Fig. 3. Prices for the valorization of production of the medium-sized crop farm
Source: Own processing based on information provided by the medium-sized agricultural plant farm

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The farm gate prices are those that directly influenced turnover in each of the agricultural years under study, and which showed increases during the period under analysis. The largest price increase is noted for soybean crop, in 2021, it increased by 73% compared to 2019 (Figure 3).

In 2020, the otherwise small wheat production was used for lease payments and not for value.

Analysing the turnover, it can be seen that at the level of the medium-sized crop farm it is composed of production sold and sales of goods, in different proportions, but the first component occupies an overwhelming share, i.e. 98.70% in 2019, 95.48% in 2020 and 97.99% in 2021. Evolutionarily, the turnover has an oscillating trend during the period of analysis, with a decrease of 44.46% in 2020 compared to 2019 and an increase of 277.68 in 2021 compared to 2020 (Table 3, Figure 4). The year 2020 stood out as an unfavorable year from an agricultural and economic point of view for farmers in the South-Muntenia Region of Romania, due to the phenomenon of frost on the ground and lack of snow leading to the almost complete destruction of crops sown in autumn.

Table 3. Turnover component of the medium-sized crop holding

| | Specification | 2020 - 2019 | | 2021 - 2020 | |
|---|---|---|---|---|---|
| | | lei | % | lei | % |
| **1.** | Income from the sold production | -1,126,839 | 54.70 | 3,912,448 | 387.59 |
| **2.** | Income from sales of goods | 31,682 | 196.89 | 43,955 | 168.27 |
| **3.** | **Turnover** | **-1,095,157** | **56.54** | **3,956,403** | **277.68** |

Source: Own processing based on information provided by medium-sized vegetal farm

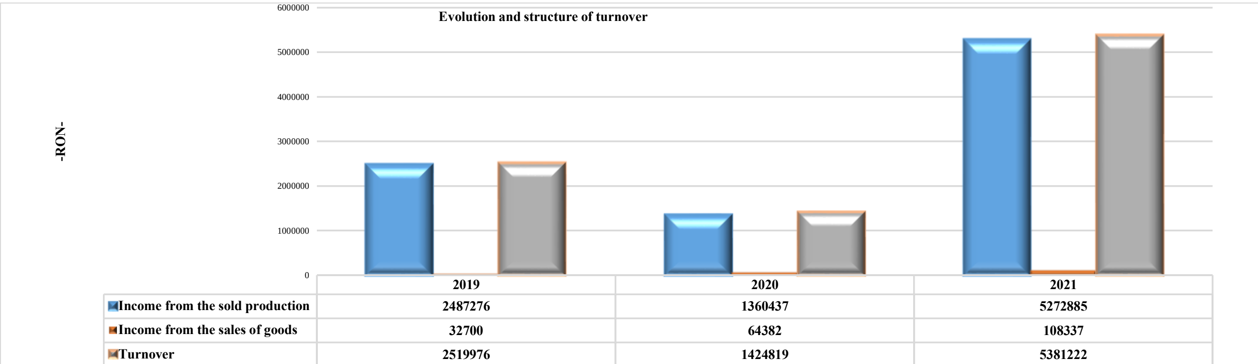


Fig. 4. Turnover - evolution and structure (Ron)

Source: Own processing based on information provided by medium-sized vegetal farm

Based on the items in the profit and loss account, the turnover rates are further determined by reference to the balance sheet items, indicators which are also referred to as capital turnover rates. Turnover rates are a qualitative factor of return on capital and express the intensity of the exploitation of the assets of the medium-sized crop farm. The more intensively they are exploited, the higher the turnover rate and the shorter the duration of a turnover. Turnover rates are expressed in two ways: by the speed of rotation and by the duration of rotation.

Table 4. Recovery period of receivables

| | U.M. | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Receivables | lei | 1,297,255 | 1,562,216 | 1,530,661 |
| Turnover | lei | 2,519,976 | 1,424,819 | 5,381,222 |
| Reference period | days | 360 | | |
| Debtor collection period | $Dcp = \frac{r \times 360}{turnover}$ | **185.32** | **394.72** | **102.40** |

Source: Own processing based on information provided by medium-sized vegetable farm.

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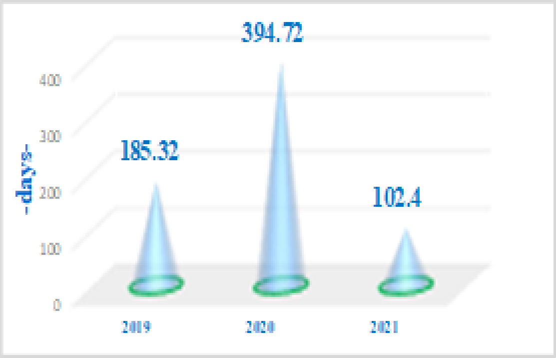


Fig. 5. Evolution of the duration of debt collection
Source: Own processing based on information provided by medium-sized vegetable farm.

The lowest receivables collection period, 102.4 days, was in 2021, due to the increased value of turnover and relative receivables constant with those of the previous year, 2020.

In 2020, this indicator recorded a maximum of the analysis period, i.e. 394.72 days.

In 2019, the average value of receivables collection was 185.32 days (Table 4, Figure 5).

Therefore, the situation regarding this indicators in the two analyzed years is different.

Table 5. Supplier rotation time/ rotation time of supplier

| | M.U. | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Supplier | lei | 494,830.45 | 494,830.5 | 310,916.1 |
| Turnover | lei | 2,519,976 | 1,424,819 | 5,381,222 |
| Reference period | days | 360 | | |
| Revolving period of debts to suppliers | $RPDS = \frac{AC \times 360}{CA}$ | **70.69** | **125.03** | **20.80** |

Source: Own processing based on information provided by medium-sized vegetal farm.

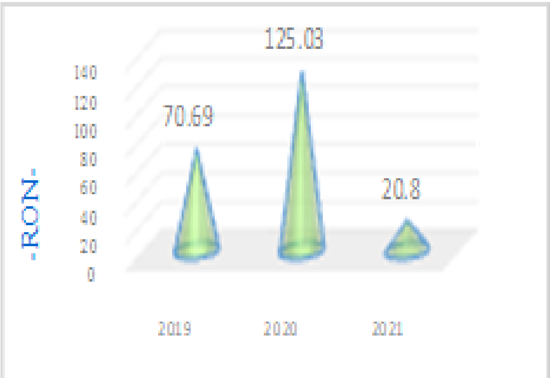


Fig. 6. Evolution of the revolving period of debt to suppliers
Source: Own design of the results.

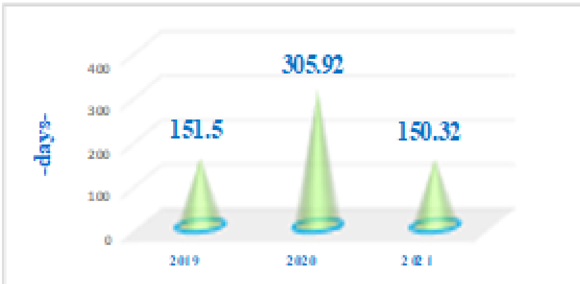


Fig. 7. Evolution of stock turnover
Source: Own processing based on information provided by medium-sized vegetal farm.

It was found that in 2021 the company's turnover of debts to suppliers was 20.80 days, which is a positive situation, compared to 2020, when the company managed to achieve a full turnover of these debts at 125.03 days. The year 2019 showed that the medium-sized agricultural holding achieved a turnover of trade debts at 70.69 days (Table 5, Figure 6).

The fastest stock turnover was in 2019 and 2021, at 150.32 days and 151.5 days respectively. The economically unfavourable year 2020 places the stock turnover level on the size farm at 305.92 days (Table 6, Figure 7).

The turnover speed of circulating assets expresses how efficiently the circulating assets of the medium-sized crop farm are used, thus, the higher the speed, the lower the volume of assets [7].

In case of the vegetal farm, the turnover speed of the current assets varied from a year to another (Table 7, Figure 8).

The number of rotations is a significant indicator that characterises the efficiency with which circulating assets are used on the medium-sized crop farm in Romania.

A more accelerated turnover is noticed in 2020, a year in which turnover is at a minimum level and circulating assets increase significantly [7].

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Table 7. Turnover speed of current assets

| | M.U. | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Current assets | lei | 2,361,603 | 2,957,881 | 1,530,661 |
| Turnover | lei | 2,519,976 | 1,424,819 | 5,381,222 |
| Turnover speed of current assets | $Vr = \frac{AC}{to}$ | **0.94** | **2.08** | **0.28** |

Source: Own processing based on information provided by medium-sized vegetal farm.

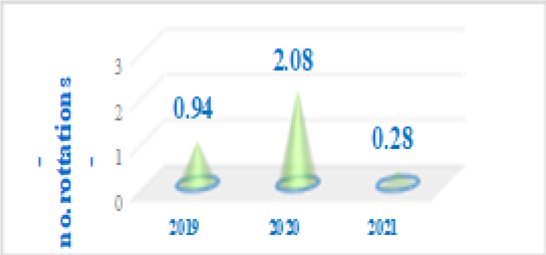


Fig. 8. Evolution of the current assets turnover rate
Source: Own processing based on information provided by medium-sized vegetal farm.

In 2019 the turnover rate is 0.94 times which denotes that in the existing circulating assets in the medium-sized vegetable agricultural holding, production is obtained with approximately the same volume of circulating assets. In 2021 the turnover rate of current assets is slowed down to 0.28 times which gives information that production and income with significantly increased values is achieved with a reduced volume of current assets (Table 7, Figure 8).

Margin ratios also referred to as commercial rates of return as the ratio of various margins to turnover will be further determined [1]. These margin rates are a quantitative factor of return on capital and can be improved by increasing sales prices with slower growth in expenses. In a situation of high competition, margin rates may not make a significant contribution to increasing return on capital.

The margin ratio of "Earnings before interest, tax, depreciation and amortisation" (REBITDA) shows the profitability of the operating activity in generating profit. EBITDA stands for "Earnings Before Interest, Taxes, Depreciation and Amortization" and in Romanian accounting, their calculation is not considered mandatory [16].

EBITDA delineates the efficiency picture and readily identifies what is left of earnings or revenues under the established name of profit after all major expenses (inventory expenses, utilities, payroll with related contributions and taxes, rent, transportation, etc.) have been paid [16].

A high value of this indicator suggests effective financial management, and a low value indicates a high operating cost in relation to sales.

Table 8. **REBITDA**

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| **Operating Surplus** | 951,833.09 | 202,975 | 2,952,773 |
| **Turnover** | 2,519,976 | 1,424,819 | 5,381,222 |
| **REBITDA= EBITDA/ turnover** | **0.38** | **0.14** | **0.55** |

Source: Own processing based on information provided by medium-sized vegetal farm

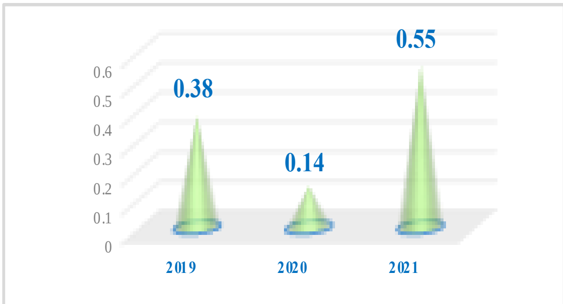


Fig. 9. Evolution of **REBITDA**
Source: Own processing based on information provided by medium-sized vegetal farm.

EBITDA is a key performance indicator [16] recorded for the medium-sized vegetal farm the highest value in 2021, a year with a significantly higher turnover than in previous years, and the year with the lowest values of this indicator is 2020, a year in which both turnover and operating surplus have minimum values (Table 8, Figure 9).

EBITDA is a method that generates a set of indicators that represent a leap in business management and decisions of the vegetal farm if based on such data, the objective of the agricultural producer essential for the farm that it represents, to make a profit [16].

The net operating margin ratio (REBIT) highlights the profitability of the farm and shows the efficiency of the medium-sized vegetable farm from a technological, administrative and commercial point of view. The indicator takes into account the depreciation policy of the assets and their possible depreciation.

For the medium-sized vegetable farm, the highest EBIT value is in 2021, this year highlighting the fact that it was the best results year in the period analysed, with turnover and operating result with highest values, the year with the lowest values of this indicator being 2020 (Table 9, Figure 10).

Table 9. $\mathbf{R_{EBIT}}$

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| **Operating result** | 503,316 | 181,277 | 2,621,150 |
| **Turnover** | 2,519,976 | 1,424,819 | 5,381,222 |
| **$\mathbf{R_{EBITDA}}$= EBIT/ Turnover** | **0.20** | **0.13** | **0.49** |

Source: Own processing based on information provided by medium-sized vegetal farm.

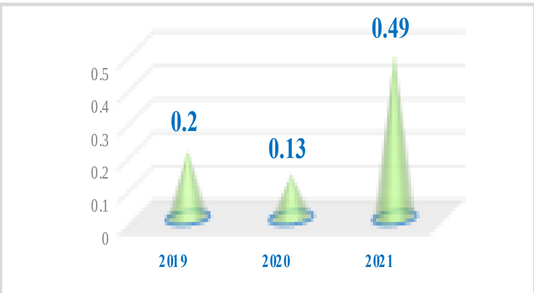


Fig. 10. Evolution of $\mathbf{R_{EBIT}}$
Source: Own processing based on information provided by medium-sized vegetal farm.

The gross self-financing margin ratio (GFR) measures the monetary surplus from which the medium-sized vegetable farm finances both its development activity and the remuneration of its associates.

For the medium sized crop farm, the highest value of GFR is in 2021, followed by 2019 and 2020, with the monetary surplus for development and associate remuneration most evident in 2021 (Table 10, Figure 11).

Table 10. $\mathbf{R_{GFR}}$

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| **Gross result** | 345,622.09 | 18,933 | 2,325,196 |
| **Turnover** | 2,519,976 | 1,424,819 | 5,381,222 |
| **$\mathbf{R_{GFR}}$= GFR/ Turnover** | **0.14** | **0.01** | **0.43** |

Source: Own processing based on information provided by medium-sized vegetal farm.

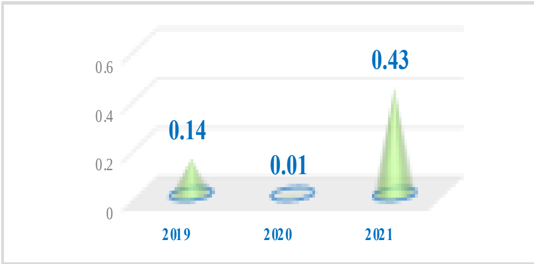


Fig. 11. Evolution $\mathbf{R_{GFR}}$
Source: Own processing based on information provided by medium-sized vegetal farm.

Net margin rate (NPR) also called commercial profitability expresses the efficiency of the entity as a whole [15]. This indicator highlights the company's ability to generate profit based on sales achieved and quantified by turnover.

Table 11. $\mathbf{R_{NPR}}$

| | 2019 | 2020 | 2021 |
|---|---|---|---|
| **Gross result** | **322,612.09** | **1,909** | **2,177,131** |
| **Turnover** | 2,519,976 | 1,424,819 | 5,381,222 |
| **$\mathbf{R_{PN}}$= NPR/ Turnover** | **0.13** | **0.00** | **0.40** |

Source: Own processing based on information provided by medium-sized vegetal farm.

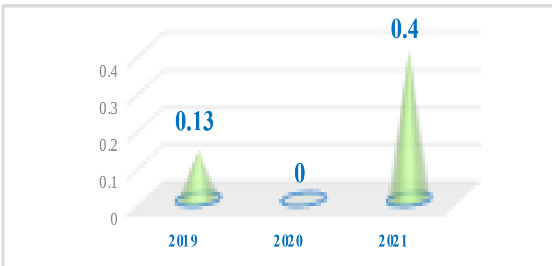


Fig. 12. Evolution $\mathbf{R_{NPR}}$
Source: Own processing based on information provided by medium-sized vegetal farm.

For the medium-sized crop farm, the highest value of this indicator is also in 2021,

followed by 2019 and 2020, when a very low net result makes the net margin rate zero (Table 11, Figure 12).
In addition to the income earned by the medium-sized crop farm from sales of products or goods, an important component of total income is the income from operating subsidies.
For the medium sized crop farm, in 2019 and 2020, operating subsidy income accounted for approximately one quarter of total annual income per farm, 23.03% in 2019 and 26.35% in 2020 against a turnover of 75.07% of total income in 2019 and 52.20% in 2020 Table 12).
The year 2021 stands out as a favourable year from a financial point of view, a year in which the income from the company's activity through sales of agricultural products and goods accounts for 84.41% of the total income.
10.38% is the percentage that highlights the income from subsidies, and the difference in income is made up of income from stored production, income from works and services rendered or the cost of production in progress.

Table 12. Share of turnover and subsidies in operating revenue

| | 2019 | | 2020 | | 2021 | |
|---|---|---|---|---|---|---|
| | **lei** | **%** | Lei | % | lei | % |
| Turnover | 2,519,976 | 75.07 | 1,424,819 | 52.20 | 5,381,222 | 84.41 |
| Income from operating subsidies | 773,240 | 23.03 | 719,224 | 26.35 | 661,957 | 10.38 |
| **Operating income - total** | 3,356,821 | 100 | 2,729,578 | 100 | 6,374,960 | 100 |

Source: Own processing based on information provided by medium-sized vegetal farm.

## CONCLUSIONS

The analysis of turnover on the medium-sized vegetal farm revealed the following:
-Turnover failed to exceed the level of operating expenses, except in 2021 when it accounted for 69.76% of turnover. In 2019 and 2020, operating expenses were 13.24% (year 2019) and 80.17% (year 2020) higher than turnover, but by offsetting this with income from subsidies and from services rendered, the value of products in stock or the value of income from production costs in progress, the company achieved a positive net financial result in each year of the period under analysis.
-In the operating revenue structure, turnover is recommended to be at a minimum level of 85% and total revenue at a minimum of 75%, indicating normality of activity. For the medium-sized vegetable farm, turnover represents 75.07% in 2019, 51.84% in 2020 and 84.41% in 2021 in both operating and total income, as financial activity is poorly represented. These percentages conclude that the activity was carried out at a normal level in 2019 and 2021 and in 2020 it is within the limits of a non-normal year, with financial results close to break-even.
-Turnover has an oscillating evolution during the period under analysis, its value indicating the vulnerability of the medium-sized crop farm to external factors with a direct influence on its formation. Through the managerial measures applied to counteract the tenological factors with a negative influence on turnover, such as limiting the effects of drought by introducing crop irrigation, the year 2021 led the agricultural company to increases of 277.68% this indicator, compared to the previous year.

## ACKNOWLEDGEMENTS

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# STUDY ON THE EVOLUTION OF THE NUMBER OF AGRICULTURAL FARMS, THEIR AVERAGE SIZE AND AGRICULTURAL PRODUCTION IN DAMBOVITA COUNTY, ROMANIA

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***Abstract***

*The purpose of this study is to objectively analyze the situation of agricultural holdings in Dambovita county, both in terms of their size and dimension, but also their evolution, with the aim of highlighting the existing gaps compared to the European Union average, problems and dysfunctions what characterizes the agricultural sector, but also its prospects for development and performance growth. The research methodology first of all assumed the analysis of specialized literature regarding the importance of agriculture for the economy and its role in increasing income for farmers, and on the other hand, the collection and processing of national and county statistical data regarding agricultural holdings. Based on the analyzed data, conclusions and recommendations were formulated regarding the reduction of existing gaps between Romanian agriculture, Dambovita County and community agriculture. It was thus established that compared to the average size of the agricultural holding registered at the national level, of 2.37 ha, at the level of Dambovita county, it is 4.37 ha. This is due to the specific relief and activity. However, the average size of agricultural holdings is well below the average size of existing holdings at European Union level, where it is 152.4 ha in the Czech Republic, 90.4 ha in the United Kingdom or 77.5 ha in Slovakia.*

***Key words:*** *agricultural holding, average size, production, area, Dambovita County, Romania*

## INTRODUCTION

The growth of the world's population, industrialization, urbanization are factors that put a direct pressure on agriculture and on the provision of food resources, which requires an increase in production, under the conditions in which environmental protection is also required.

Under these conditions, establishing the optimal size of agricultural holdings represents an important measure in ensuring productivity, conditioned by sustainable development, which is a concept that governs all fields of activity in the modern world and which must be supported by political and economic instruments. In the agriculture of the European Union, the formulation of these policies is influenced by the size of agricultural holdings, which differ not only between member states, but also at the level of individual countries [10, 15].

Over time, the size of agricultural holdings was influenced by the transition from extensive agriculture to intensive agriculture, which made the average size inversely proportional to the labor force in agriculture, which in turn was influenced by the modern technologies used, by the mechanization of agriculture, the use of imputations with increased yields, etc. [6, 7].

Starting with the 60s, different currents of opinion were outlined regarding the relationship established between the productivity of an agricultural holding and its size. There were specialists who considered that the dependent relationship is directly proportional [1, 3, 5, 13], while others considered that this cannot be demonstrated [2, 8, 12, 20], under the conditions that productivity is influenced by many other factors. And in Romania, specialized works tried to confirm or deny the relationship between the size of the agricultural holding and its profitability [4, 11, 14]. However, whatever the opinions related to the size of agricultural holdings, this is an important topic in the development of agricultural policies, in measuring efficiency, in supporting financing policies.

Equally important are the creation of partnerships between producers, a better integration of agriculture, sustainable rural development, ensuring the constant demand for agricultural and food products by consumers, reducing the trade deficit,

increasing the standard of living, ensuring food security, etc. that is, aspects that must be analyzed in accordance with the size of the agricultural holding [16, 22].

At the moment, in Romania, agriculture At the level of Romania, one of the important sectors of the economy is agriculture. In 2021, this had a 4% contribution to the Gross Domestic Product [21]. As a member state of the European Union, Romania has a high potential in this sector of activity, being in sixth place in terms of used agricultural area among EU countries, which amounts to 13.9 million hectares. Of this area, almost 60%, i.e. 8.2 million ha, is arable land, of which approximately 5.5 million ha are intended for the cultivation of cereals, which makes Romania one of the top 10 exporters of cereals worldwide. In 2021, it held the 9th place in the export of wheat, the 8th place in the export of sunflowers and the 6th place in the export of corn.

Compared to the other member states of the European Union, Romania is the country that registers low yields of agricultural production [19, 20]. At the level of 2021, the productivity recorded by the agricultural holdings was only 25% compared to the average productivity recorded in the agricultural holdings of the member states.

Another aspect that must be analyzed is the one related to the fragmentation of properties. Romania is in the last place among the states of the union from this point of view, an aspect that influences the size of agricultural holdings. Other countries facing the same situation are Malta and Cyprus. In terms of number, agricultural holdings in Romania have a weight of 35% of the number of community agricultural holdings. Of their total, over 98% have areas smaller than 10 ha, but the area owned by them represents only 39% of Romania's agricultural area. The number of agricultural holdings with areas larger than 100 ha represents 0.5% of the total number, holding 49% of the agricultural area.

The average size of an agricultural holding in Romania is 3.65 ha in 2020, larger by 0.15 ha compared to 2010, but still far behind the European Union average where the average surface is 16.6 ha.

As far as the capitalization of agriculture is concerned, it is quite low, affecting the yield of productions obtained and placing Romania in the penultimate place among the countries in the European Union [9]. According to data from 2021, approximately 2% of the number of agricultural holdings own at least one tractor. Other problems of Romanian agriculture are related to the lack of irrigation systems, the farmers' reduced spending on plant protection products, poor integration of production, the extensive areas affected by soil degradation, the lack of efficient collection and storage systems, poor processing capacity, aging workforce, low level of professional training, low level of association, credit systems not adapted to farmers' needs, etc.

## MATERIALS AND METHODS

The methodology that was the basis of the research carried out involved the use of analysis methods and techniques based on the principle of triangulation. Thus, the collected data were processed and interpreted, being able to formulate conclusions and recommendations regarding the development direction of agriculture in Dambovita county. The three types of methodological tools were data collection methods, quantitative analysis methods and qualitative analysis methods.

Starting from the bibliographic study regarding the role that agriculture has in the economic development of Romania, as well as from its place within the economy, the ways of determining the optimal size and size of

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agricultural holdings were sought, with the aim of increasing profitability.

The qualitative and quantitative analysis was based on the statistical information collected both at the county and national level. The statistical information was collected at a level of aggregation that made possible the relevance of the analysis carried out in the report. The statistical data were taken from the Statistical Yearbook of Dambovita County, for the period 2016-2020 and were processed using the following methods:

- The dynamics index with a fixed base, to determine the increase or decrease from 2020 compared to 2016:

$$IFB = (x_n/x_1) \times 100 \qquad (1)$$

- The graphical illustration of the dynamics highlighted the regression model and the coefficient of determination

## RESULTS AND DISCUSSIONS

The statistical data published in March 2022 show that in 2020 there were 2,887 thousand agricultural holdings in Romania, a decrease of approximately 970 thousand holdings compared to 2010. This decrease led to an increase in the average agricultural area of 28% in 2020 compared to 2010, that isan increase of 0.97 ha. At the same time, the agricultural area used was 12.8 million hectares in 2020, 543 thousand hectares less than in 2010, which is a decrease of 4.1%.

Regarding the decrease in the number of agricultural holdings, it should be added that the biggest decreases were recorded for very small holdings. In the case of holdings with an area of less than 0.1 ha, the decrease was 6% in 2020 compared to 2010. For agricultural holdings with an area of more than 10 ha, however, increases were recorded, being 2% in 2020 compared to the year 2010.

According to the data from the 2020 General Agricultural Census, it can be seen that in the last ten years there have been changes regarding the agricultural area used and the number of agricultural farms. Percentage-wise, it was found that 54% of the agricultural holdings had an area of less than 1 ha, 36% of them had an area between 1-5 ha and only 1% of them had an area of more than 50 ha. On the other hand, very small agricultural holdings (under 1 ha) exploited 5% of the total agricultural area, and those between 1-5 ha, exploited 18% of the total area. However, agricultural holdings with an area of more than 50 ha exploited 54% of the total agricultural area.

It was also noted that the average agricultural area for entities with legal personality was 2.73 ha in 2020, and for agricultural holdings without legal personality, it was 194.78 ha, compared to 1.95 ha, respectively 190.78 ha in 2010.

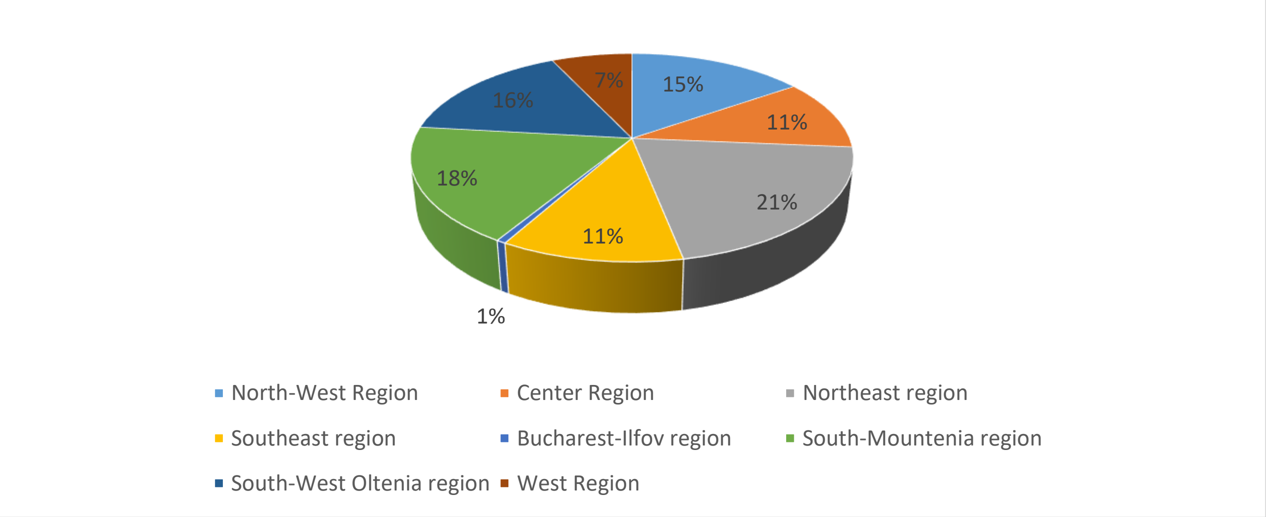


Fig. 1. Structure of agricultural holdings, by region, in 2020 (%)
Source: own processing [17].

From the total of 2,887 thousand agricultural holdings, the largest share (21%) is in the North-East Region, followed by the South-Muntenia Region (18%) and the South-West Region - Oltenia (16%). The lowest share of agricultural holdings is in the Bucharest-Ilfov Region, with approximately 1% (Fig. 1).

From the point of view of the agricultural areas used, based on the data provided by the General Agricultural Census 2020, it is found that there are variations in the average areas at the regional level. The largest average area is recorded in the West Region (7.46 ha), followed by the South-East Region (6.71 ha) and the Center Region (5.05 ha). The smallest average area is recorded in the North-East Region, with an average area of 3.09 ha. The Bucharest-Ilfov region registers an average area of 4.65 ha (Fig. 2).

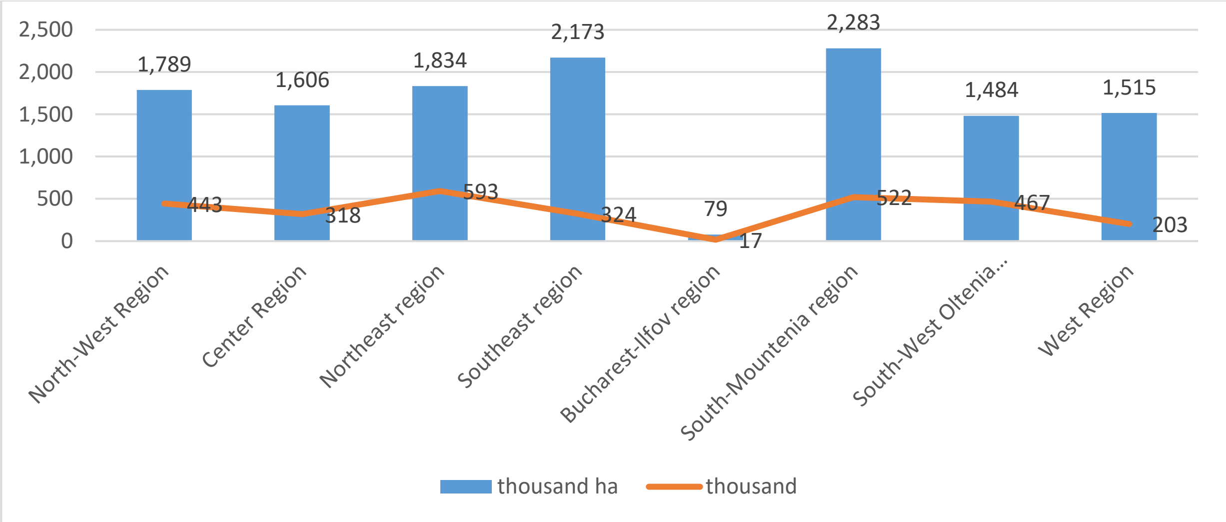


Fig. 2. The situation of agricultural holdings and surfaces, by region, in 2020
Source: own processing [17].

Dambovita County is part of the South-Muntenia Region, a region where the average area of the agricultural holding is 4.37 ha.

The area of the land fund of the county, in 2020, was 404,542 hectares. Of its total, 60% is the agricultural area, whose distribution is as follows: 172,820 ha of arable land, 39,190 ha of pastures, 20,679 ha of pastures, 11,173 ha of fruit orchards and nurseries and 320 ha of vineyards and wine nurseries.

The cultivated area in 2020 was 170,609 ha, increasing by 8.5% compared to 2016 and 3.4% compared to the previous year (Fig. 3).

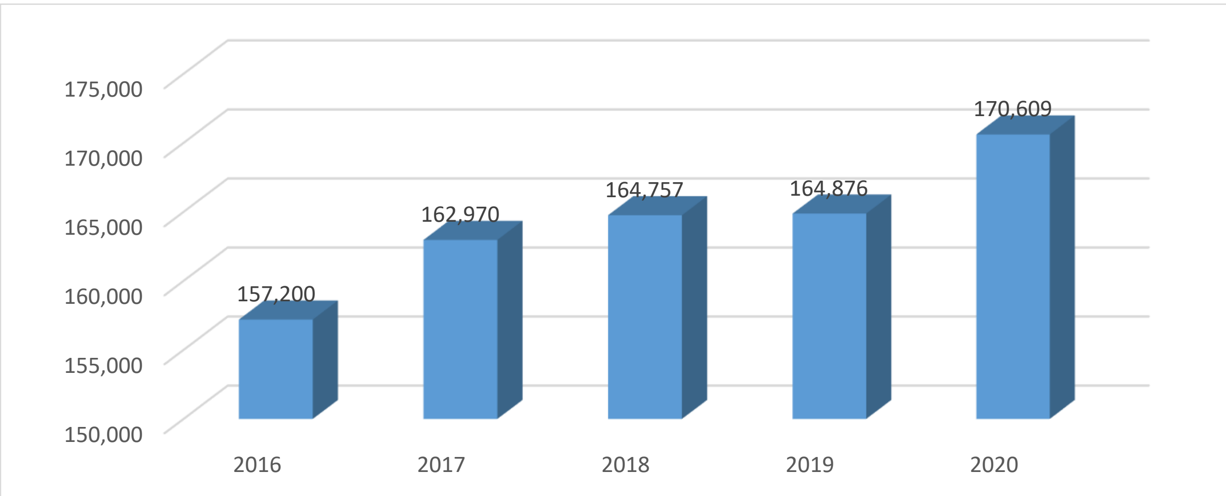


Fig. 3. Evolution of the cultivated area in the period 2016-2020, in Dambovita County (ha)
Source: own processing [17].

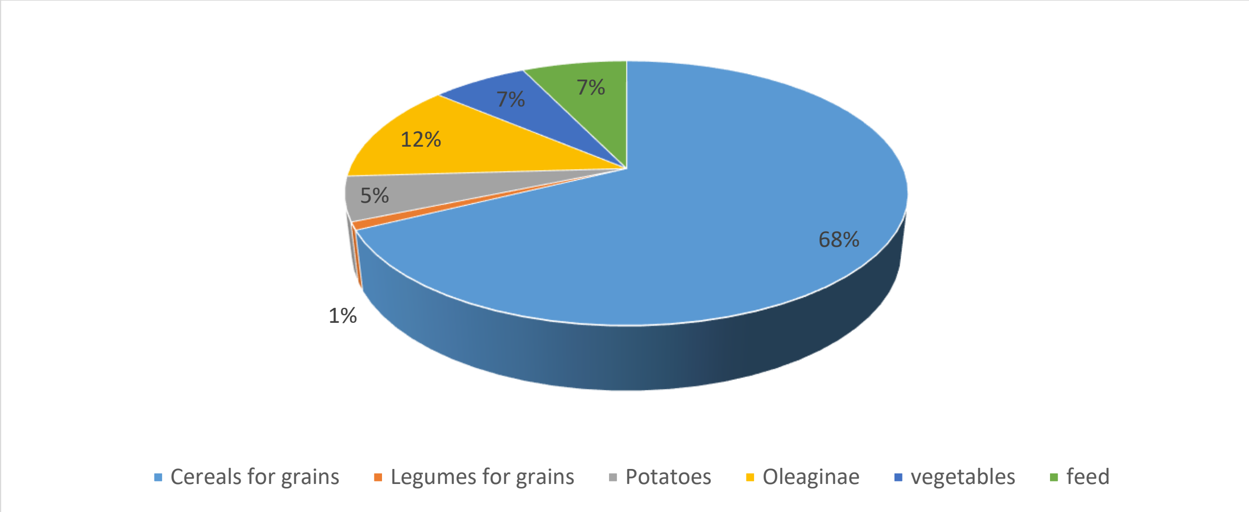


Fig. 4. The structure of the cultivated area in Dambovita County, in 2020
Source: own processing [17].

Of the total cultivated area (Figure 4), 68% is intended for the cultivation of cereals, 12% for the cultivation of oleaginous plants, 7% each for the cultivation of fodder and vegetables and 5% for the cultivation of potatoes.
Regarding the average productions per hectare, it is noted that they decreased in 2020 compared to 2018 for cereal for grains, legumes for grains, oilseeds and vegetables. The only increase was recorded in potatoes. Regarding cereals, the decrease in 2020 was 22 percentage points compared to 2018 and 6% compared to 2019. The average production of legumes for grains, although it increased by 13 percentage points in 2019 compared to 2018, decreased by 25 percentage points in 2020. In potatoes, the average production decreased by 6 percentage points in 2019 compared to 2018, but increased by 6 percentage points in 2020 compared to 2018. In oleaginous plants, the average production increased by 12 percentage points in 2019 compared to 2018, and a decrease of 11 percentage points in 2020 compared to 2018. Regarding vegetable production, it decreased by 6 percentage points in 2019 and by 20 percentage points in 2020 compared to 2018. Dambovita County is one of those that have a large area occupied by fruit plantations (Fig. 5).

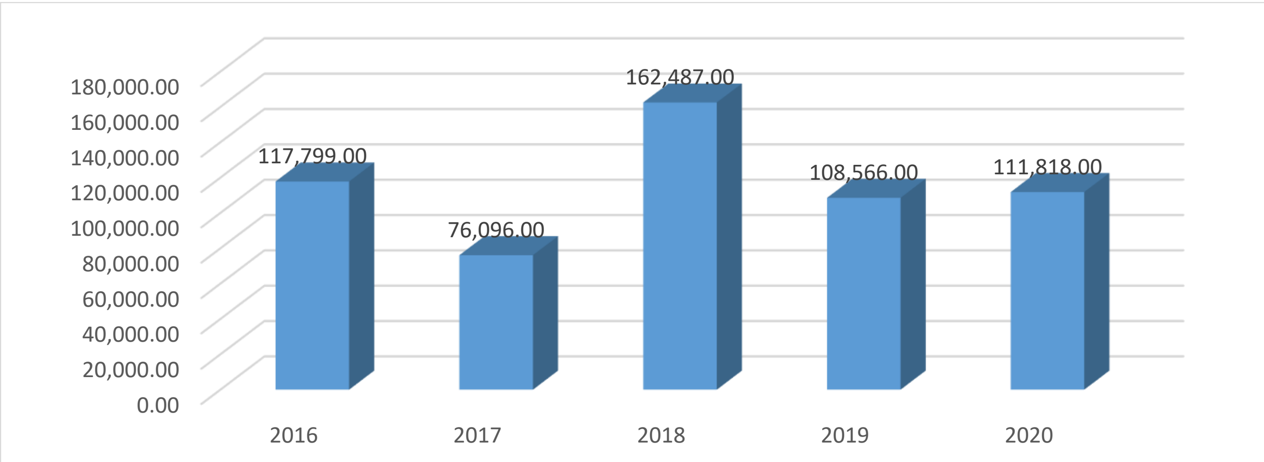


Fig. 5. Evolution of total fruit production in Dambovita county, in 2020 (tons)
Source: own processing [18].

Regarding the structure of fruit production, in 2020, in Dambovita County, the largest shares were held by apple production (52%) and plum production (40%). The difference of 8%

was shared by the production of pears (4%), cherries and cherries (2%), apricots and cherries (1%) and peaches (under 1%) ( Fig. 6).

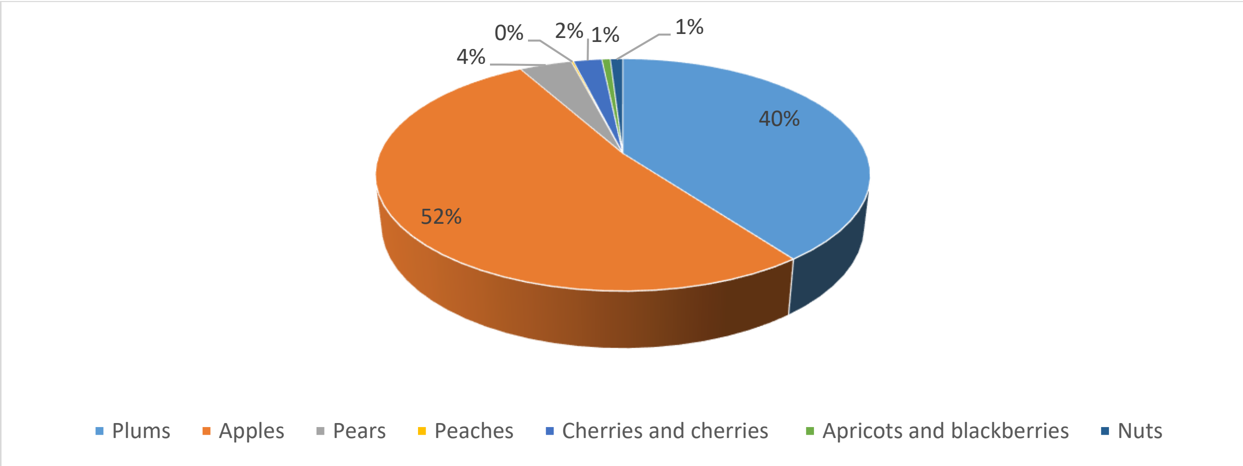


Fig. 6. Structure of total fruit production in Dambovita county, in 2020 (%)
Source: own processing [18].

## CONCLUSIONS

Romania's agriculture, and therefore that of Dambovita County, represents a sector of the economy that has potential for growth. At the analyzed county level, agriculture is an economic activity that contributes approximately 8% to the gross added value of the county.

Vegetable production is mainly oriented towards the cultivation of grains, potatoes, vegetables and fruits. The production of vegetables, fruits and potatoes places Dâmbovița county in the category of the largest producers at the country level. We note that as regards the average size of an agricultural holding, it was 4.37 ha at the level of 2020, being far below the average size of community agricultural holdings. In the Czech Republic the average surface is 152.4 ha, in England it is 90.4 ha, in Slovakia the average surface is 77.5 ha, in Denmark the average surface is 62.9 ha, and in Germany the average surface is of 55.8 ha.

However, the average area is 60% higher than the average of agricultural holdings registered at the national level (2.73 ha).

The need to increase the average areas is determined by obtaining production increases that contribute to increasing the profitability of farms, which are related not only to the increase of the area, but also to the realization of investments, the use of high-performance production systems or the development of agricultural entrepreneurship.

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# FOOD WASTE STATUS AND REDUCTION THROUGH THE CIRCULAR ECONOMY

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***Abstract***

*Food waste and the circular economy are two major topics that the Earth's population should be concerned about. The circular economy has been discussed on a regular basis as a mechanism of better waste management through recycling, reuse, and recovery. As a result, this paper's aim is to reveal a comprehensive look at alternate solution implementations over the whole life cycle of any process, as well as the relationship between processes, environment, and economy. The research question is whether the circular economy is related to food waste, starting from the assumption that food waste can be prevented by applying the principles of circular economy. The findings show that the EU 28 contributes significantly to the global 1.3 billion tonnes of wasted food each year, while the cost of covering the 180 kg/capita of food wasted each year in the EU 28 raises up to 25% of the food products acquired, evidencing a massive monetization and a possible material overturn if this issue of reducing food waste is not properly managed. The relevance of the results consists in the fact that circular economy inspires new patterns and behaviors to consumers, assisting them in achieving greater sustainability. As a result, disposed food is no longer considered as a waste or energy recovery problem, but rather as an opportunity to enhance the overall system.*

***Key words*: *circular economy, food waste, EU 28, disposal of food, household food waste***

## INTRODUCTION

Over the time, food waste has significantly affected sustainability. This, combined with the consumption of meat and dairy products, is currently having a huge impact on the food systems.
Circular economy is part of the wider concept of green economy that implies fully reusable and recyclable material resources [20].
Food waste reduction is part of the European Union's Circular Economy Strategy, because of its three-dimensional importance determined through the impact over economic, environmental, and social aspects of any policy [38]. According to the European Commission (EC) [15], the goal of this strategy is to maximize resource efficiency by preserving the value of materials and expanding the product life cycle loop, to have an easier transition towards a circular economy (CE) that requires changes in technological infrastructures, business models and consumption practices in order to make this transition much easier [21].
The effects of human actions on the environment are causing significant worldwide challenges in our post-industrial era. These challenges necessitate a reconsideration of how we structure our economic and social relationships, which today appear to be bound by traditional technologies, lifestyles, supply chains, and organizational, regulatory, institutional, and political frameworks. The need for a transition to a circular economy has already been raised on the global policymakers' agenda, and it is already part of the strategic plans of established enterprises and sectors. Furthermore, significant issues persist for the actors involved in this change to overcome and make the required movement towards fully embracing the circulator economic model that represents the transition to sustainability [3].

The food sector, being one of the world's largest industries, is essential to the economies of many countries. Therefore, in the next 50 years, the increasing global population and food supply chain demands will determine a steep increase in food output [35].

Resources and environmental repercussions are sacrificed in vain when food is thrown away. Enhancing the usage of food produced and reducing waste are both necessary to fulfil the growing food demand in the face of threatening climate change effects and sustainability orientation [19]. In the products' route, from farm to fork, food waste occurs at every stage of the food chain. The last stages of the food chain, which include consumer-facing enterprises (hypermarkets, supermarkets, grocery stores, distribution facilities, restaurants; institutional food services) and residences, generate most of the food waste, especially in industrialized economies [13].

As people's living levels rise, businesses will change product proportions to accommodate customer psychology or remove large amounts of edible elements in the pursuit of high-quality items. As a result, vegetables, fruits, and other foods are thrown out due to their shape or expiration date, among other factors. Food waste is a major issue today, and it's becoming an increasing concern for many countries around the world. There has already been a lot of research done on food waste from the point of origin to the point of sale, and several restaurant management practices have established zero-waste policies [25].

Waste has become omnipresent around the globe, and natural resources are in higher demand than ever. Predictions indicate that about 80% of all materials and consumer items are discarded, and approximately 30% of processed food is discarded after it enters the food supply chain. The CE model promotes environmental conservation and social prosperity, as well as economic growth that is consistent with long-term development.

In this context, this piece of research has the objectives to reveal the relationships between food waste, environment, and economy, and, furthermore, to identify solutions for reducing food waste. It answers the question whether the circular economy is related to food waste. To achieve the research goals, a documentary study has been developed and statistical data have been introduced in econometric programs. The hypothesis tested in this article is that food waste quantities have increased in the last period, data evidencing the materiality of this issue transformed the topic of food waste into a global issue.

In the past few years there is an increased interest in food waste and abundant literature on the topic. The researchers [22, 26, 28, 33] were preoccupied by the legal framework of food waste, its hierarchy, reduction, donation, animal feeding and so on.

The increasing popularity of the topic of circular economy is also observable in the academic literature. In the last couple of years an increasing interest has been marked in various related aspects of this topic, including its implementation [10]. The paper's topic has its origins in industrial ecology, a concept that targets collaboration between the private sector and various production mechanisms [12].

Industrial ecology is also presenting the direct benefits of waste recycling through diverse linkages in various industrial collaborative projects [1].

Discarded food is common throughout the entire supply chain, even though it has all the properties to be edible for human consumption. Estimations account up to 30% of worldwide food production being wasted [18], fact that is significantly impacting the actual food systems that are already raising different uncertainties related to environmental boundaries as landfill still represents a used method for waste disposal in various states, resulting in chemicals known as contaminants (leachate, methane, and other greenhouse gases), whereas methane has more than twenty times negative impact than carbon dioxide. This resource resulting from landfilled food, isn't properly used as it could be valued through valorizing its heating and cooking properties [33]. Reduced or fully eliminated discarded food will result in an improved food system [27] and improve food security and smart resource use.

The shifting of laws and regulations is pushing a reduction in the amount of trash that is generated, and it is encouraging the development of an economy based on biomaterials. This because these processes produce products and materials in a way that is more circular and sustainable. In addition, exhaustive research on the recovery of different products is required to address the present issues facing food waste biorefinery, bioeconomy re-engineering of food waste. Accordingly, different methodologies look at the current state of the art regarding biorefineries that process waste from food production. A critical analysis of recent research that has concentrated on food waste biorefineries that are used to produce biofuels, platform chemicals, biopolymers, bio-based fertilizers, bio-based enzymes, proteins, and other bio-based compounds and materials, is presented. In addition, an evaluation of the process of shifting from a linear economy to a more circular economy by meeting the objectives of sustainable development has been carried out. The technological obstacles that must be overcome to implement a zero-waste policy are explained, and various scenarios are analyzed [41]. The integration of processes that produce products and materials in a more circular and sustainable fashion is the only scenario for food waste valorization that will allow for the achievement of the sustainable development goals. This is because it is the only scenario that will allow for the valorization of food waste. There is no other way to salvage value from food scraps but this one.

Worldwide waste challenges can’t be solved through an unequivocal direction, therefore the impossibility of having a common action framework on waste management throughout industries, states, and people. Legislated action points have been undertaken regarding generation and management of waste to provide some wider solutions, such as the Directive 2008/98/EC of the European Parliament that aims at diminishing harmful effects of human health and environment.

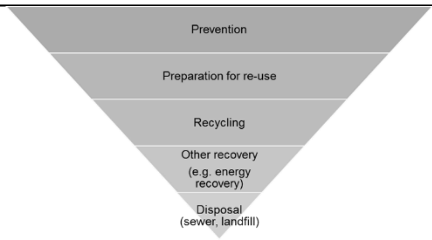



Fig. 1. Waste hierarchy
Source: Adapted from European Commission [16].

The directive of the European Parliament has highlighted the importance of prevention and reuse (material or energetical) of waste. As presented in the above figure, the directive is also establishing the hierarchical importance of all waste management stages, once again discrediting landfill disposal.

Food waste is more often presented as a global challenge, its conceptual framework is described in Figure 1. Authors [36] have adopted the EU waste hierarchy framework and adapted it across the entire food supply chain; double categorization was necessary to distinguish what can be recovered as part of the food excess, action situated at the waste prevention stage in the initial hierarchy. This novel definition is also including edible materials that reach the end-stages of the food supply chain.

Efficient management is mandatory as surplus of food is often the straightest solution for improving food insecurity. Food surpluses would have to be better integrated into a redistributive system and could be part of diverse food waste treatments such as donations, animal food or anaerobic digestion.

Organic waste reduction is becoming an increasingly important concern of businesses, organizations, governments, etc. due to the scandalous amount of food being brought from the field to the table. The aim is to prevent overproduction and the oversupply of food beyond what is needed for human consumption at all stages of the food value chain.

Retail also includes the avoidance of excess food [36]. Food waste can be easily reduced by managing inventory to minimize excess while maximizing shelf replenishment and warehouse life.

Sharing food to those in need through donations is more at hand in current times as food networks can contribute to offering working systems, enhancing the continuous work into sustainably assisting the efforts towards ensuring the food security and safety.

Developing countries are facing difficulties in fully implementing the anaerobic digestion due to technical difficulties, insecure operations, and insufficiently enough waste management [34].

One example of smart alternative energy source is the biogas resulted from anaerobic digestion that is substituting the fossil fuels, making this resource a viable combustion alternative [29]. Resulted heating could become a temperature maintainer and if it is used in electricity generation, could also input the public grid [31].

Through different schemes, companies could create strategies to face businesses challenges by starting up new CE models so that bigger profits will appear for example by making use of by-products.

With around a third of all food produced for human consumption being lost or wasted [18], the use of this material has the potential to dampen demand for land.

As the concept of circular economy itself is based on the waste collection and fully elimination of debris [11] including food waste, an important aspect that current research piece is tackling through the following parts.

**Current food waste situation**

The generator sources of the wastes described below are attributed to both production and consumption activities. These datasets refer to as waste, to any substance or object that is discarded or is intended-required to be discarded as defined by Eurostat. In order to fully understand the food waste generation phenomenon, several databases have been interrogated at a total EU 28 level and by each member state in order to design an empirical analysis.

Food waste is a major economic, social, and environmental problem. Food waste management and reduction is a strategy to reduce production costs and maximize the food performance of the system, promote food and nutrition security, and contribute to a greener food system. Food demand management, including waste minimization, is an important aspect of developing sustainable food systems to accommodate the world's increasing population [32].

One third of the world's food output, or over 1.3 billion tonnes, is discarded annually. Researchers measured that even in Australia food waste is representing a major issue, residents generating in 2014-2015 around 3.1 mt of wasted food, resulting around 133 kg for each person. In the current world that is focusing on climate change and looking deeper in possible environmental crisis, wasted food generated by households is seen not just as a loss of finite energy and water, but also as an environmental issue due to emissions and toxic waste from deteriorating food waste in overburdened municipal landfills [43].

Food waste management integration, on the other hand, could have an influence on both municipal solid waste and liquid waste systems in terms of collecting, distribution, processing, and placement. Consequently, trying to divert food waste could relieve the load of solid waste intervention, potentially reducing adverse environmental effects from waste disposal in landfills or incineration, reducing energy use and greenhouse gas emissions from waste transportation, and reducing genetic disorder vectors [44].

The integrated resources and consequences that occur along the supply chain that brings food to customers' tables are included in the external impacts of food that is wasted (or consumed). In plenty of other words, thrown out food wastes resources and has unintended environmental implications. Food waste at later stages in the supply chain (i.e., at the retail and consumer levels) has accumulated more integrated asset use and affects than end up wasting at prior stages of production, and as such strategies to reduce waste at all these later stages are especially essential for the sustainable development and a great stage for circular economy [9].

Food supply chain sustainability is dependent on resource conservation, particularly water and energy preservation, while also food waste reduction and environmental quality implications. Beyond the manufacturing of raw materials, the section of the food industry in industrialized countries consumes around 80% of the total energy required to distribute and prepare food for human consumption. Furthermore, these same sections of the food chain require a large quantity of fresh water, and well over 20% of the food is lost after delivery to the customer. Every market and procedure assessment is necessary for a comprehensive method for enhancing the food supply system's sustainability [24].

In order to decrease the food insecurity through reducing wasted food it is mandatory for all stakeholders to better collaborate across the chain, to provide comprehensive agricultural solutions and smartly resolve any supply-demand bottlenecks [37].

After the introduction, the literature review reveals the main streams of ideas about food waste and circular economy presented in scientific papers.

Then, the data about food waste are presented and analyzed, being discussed further as compared to the findings of other researchers. Finally, conclusions are drawn in the last part of the paper.

## MATERIALS AND METHODS

As stated by [4] and [14] the EU 28 countries household food waste is more significant than the rest of the food supply chain, shrinking households' quantities of food waste could be seen as considerable effort towards reaching the EU targets for reducing food waste.

An important part of the following analysis will also be focusing on representing food waste through the importance that it pays in the process of fully transitioning the economy to a circular one. Biowaste, as stated by the data collectors (Eurostat in this paper's case), includes among others, food and kitchen waste from processing entities, offices, restaurants, retails and households as described by the Implementing Decision 2019/1004/EC and 2019/1885/EC.

Europe was the first continent to make strides toward minimizing and eliminating food waste as part of efforts to establish rules and strategies for the sustainable production of materials and chemicals. The legislation and restrictions prompted many businesses to rethink their methods of production, and they began transitioning towards technologies that were more environmentally friendly as a result. Therefore, accelerating the achievement of the sustainable development goals can be accomplished by transforming food waste into biofuels, bio-based fertilizers, bio-based enzymes, chemicals, proteins, and other bio-based compounds and materials. In addition, it has the benefits of (i) achieving the goals of zero waste generations; (ii) reducing or eliminating problems associated with waste management; (iii) reducing or eliminating costs associated with waste management; (iv) contributing to the sustainable production of materials and chemicals; and (v) fostering a circular bioeconomy. Consequently, the utilization of environmentally friendly technology for the recuperation of more valuable goods from food waste contributes to the reduction of environmental concerns [34].

Food waste results in a sizeable quantity of societal and environmental expenses; hence, the recovery of this resource has the potential to have a big and overwhelmingly beneficial effect on both society and the natural world. In developed nations, food waste is related with the actions of consumers, whereas in underdeveloped nations, it is associated with a lack of technological capabilities. consumer behavior is to blame for food waste in developed nations.


Fig. 2. Circular loops concerning the use of the technology "compost" for recycling household food waste
Source: Edited by the authors from [3].

According to a survey published by the "US Department of Agriculture," over 30 percent of food is wasted at the consumer and retail levels each year, which amounts to about 66.5 million tons and results in a financial loss of USD 161 billion [5].

Food waste across the supply chain in current practices, in the decreasing order of the added value, are ending as animal feed, composting, incineration or landfill.

Cost effectiveness comes from the route of completely reusing the food scraps in the animal feed processing processes [29].

## RESULTS AND DISCUSSIONS

Food waste has been recognized as a worldwide issue with global ramifications due to its ecological, socioeconomic, impact, necessitating a revolution in governmental measures.

The agri-food supply chain's transformation to a Circular Economy will necessitate adequate support structures.

Worldwide, one-third of all food is thrown away, resulting in by-products that might be recovered and reintroduces in the commerce. In the low - carbon economy, analyzing the accessibility of recycled products and identifying the various conversion systems qualitatively and quantitatively is critical for the change to take place.

Able to fully recover and using this irreversible green waste percentage might be regarded a new method of resource extraction capable of decreasing non-renewable reserve reduction. As a result, vegetative biomass may be converted into petroleum products [40].

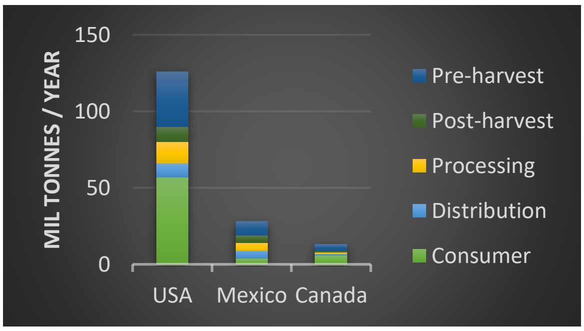



Fig. 3. North America food loss and waste estimates across the supply chain

Source: Edited by the Authors from The European Commission [16].

In order to validate the research hypothesis, the empirical structural data analysis has been chosen as the main method through multiple visual correlations and descriptive statistics. The dataset has been obtained from open-source international sites such as Eurostat and other UN databases.

Figure 3 illustrates the food loss and waste in North America, showing that the food is largely wasted to consumers, rather than in other stages of the supply chain.

According to Figure 4, those averages of the food waste percentages across multiple research papers, regarding food waste in European Union are generated throughout the whole supply chain. The most significant impact comes during the consumption phase that accounts more than the food wasted in the primary production and processing stages.

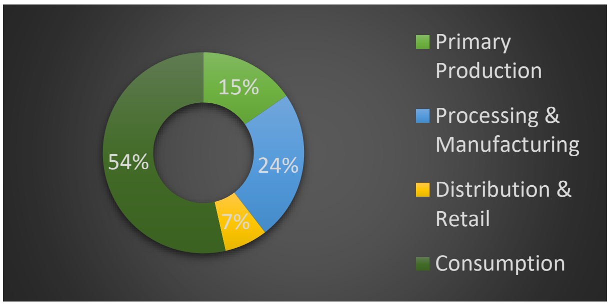



Fig. 4. EU 28 Food waste obtained split by supply chain actor presented as an average from multiple studies

Source: Edited by the authors from [6, 25, 26].

This fact that is not only applicable for the EU 28 countries as seen in the below worldwide representation where the consumption part takes most of the space in the food wasted across the supply chain, idea that is also represented in the following analysis.

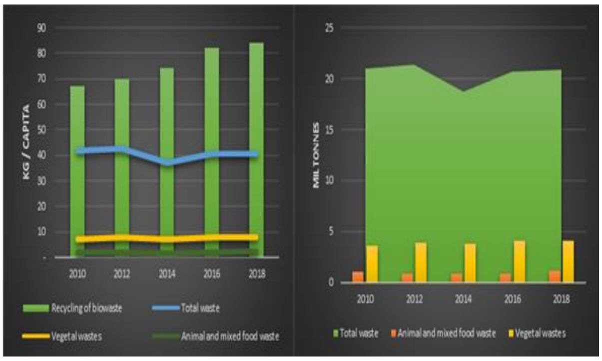



Fig. 5. (Left). EU 28 Agriculture, forestry and fishing food waste (vegetal; animal and mixed food waste) out of total waste compared to the recycling rate of biowaste (Right). EU 28 Agriculture, forestry and fishing waste structure (vegetal; animal and mixed food waste out of total waste)

Source: Edited by the authors from Eurostat [17].

As seen in Figure 5 (left), the kilogram per capita of biowaste recycled is significantly higher than the food waste generation rates for both vegetal and animal sector. The statistical indicators are separately analyzed in Table 1. The Figure 5 on the right side presents the effective waste materiality across EU 28 agricultural production stages.

We can clearly distinguish that animal and mixed food wastes are an insignificant part of the total wastes, for example in 2018, this category accounted 6% of total waste, a 16% increase over 2010, but taking vegetal wastes together with animal and mixed food waste then, on average, these two categories make up almost a quarter of the total wasted amounts across the studied period.

When considering agriculture, forestry, and fishing's food waste, it automatically ties back to a special stage in the supply chain, this specific stage where agriculture could be mapped against is definitely – Primary production, pre-harvest and post-harvest, stages that also include initial storage and freight. Possible wasted quantities in the vegetal/crops sector include non-harvested edible products, products that are edible but left on-field, harvested products not commercialized, rotten harvest, fruits or vegetables harmed by processing equipment, spilled substances, damaged products due to inappropriate handling and storage. Thinking about the animal production, most food waste along the limited supply chain, in the production stage, relates to directly discarded fish or other foodstuff and another contributing factor to the food waste's number may be caused, due to precarious storage and freight [39].

As seen in Figure 6 (left), the kilogram per capita of biowaste recycled rate is no longer more significant than the generative rates, in both vegetal and animal sector for households, with numbers that are on average up to 5 times more significant to the recycling rate of biowaste, indicating that households-final consumers' efforts are incomparable to discarded amounts, the statistical indicators are separately analyzed in Table 1. The right-hand side part of Figure 6 is presenting the effective EU 28 food waste at this level of the food supply chain.

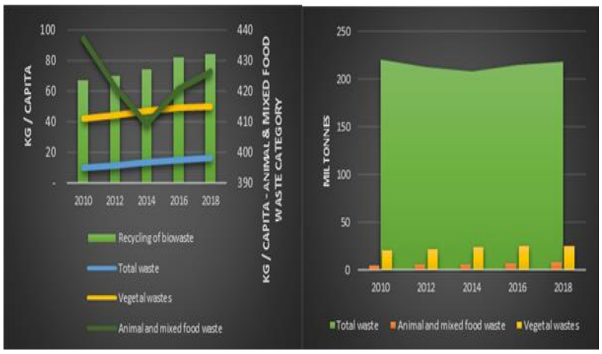



Fig. 6. (Left). EU 28 Households food waste (vegetal – left vertical axis; animal and mixed food - right vertical axis waste) out of total waste compared to the recycling rate of biowaste (Right). EU 28 Households waste structure (vegetal; animal and mixed food waste out of total waste)

Source: Edited by the authors from Eurostat [17].

Table 1. Descriptive statistics for EU 28 food waste from Agriculture… and households

| Sector/Variable Fig 5 & 6 | Recycling of biowaste kg/capita | *Households* | | |
|---|---|---|---|---|
| | | Total waste kg/capita | Vegetal wastes kg/capita | Animal and mixed food waste |
| **Min** | 67 (2010) | 9.7 (2010) | 42 (2010) | 409.3 (2014) |
| **Max** | 84 (2018) | 16.5 (2018) | 50 (2018) | 437.1 (2010) |
| **Average value** | 75.4 | 13.1 | 46.4 | 422 |
| **Var newest/oldest** | 25% | 70% | 19% | -2% |
| **Std Dev** | 7.4 | 2.7 | 3.3 | 10 |

| Sector/Variable Fig 5 & 6 | *Agriculture, forestry and fishing* | | |
|---|---|---|---|
| | Total waste kg/capita | Vegetal wastes kg/capita | Animal and mixed food waste |
| **Min** | 36.8 (2014) | 7 (2010 & 2014) | 1.7 (2016) |
| **Max** | 42.4 (2012) | 8 (2012, 2016, 2018) | 2.2 (2018) |
| **Average value** | 40.4 | 7.6 | 1.8 |
| **Var newest/oldest** | -2% | 14% | 14% |
| **Std Dev** | 2.1 | 0.5 | 0.2 |

Source: Edited by the authors based on the results.

We can clearly distinguish that animal and mixed food wastes are an insignificant part of the total wastes, for example in 2018, this category accounted 4% of total waste, seeing an increasing trend over the years with a 74% increase over 2010. Even when considering taking vegetal wastes together with animal and mixed food waste then, on average, these two categories make up just 14% of the total wasted amounts across the studied period.

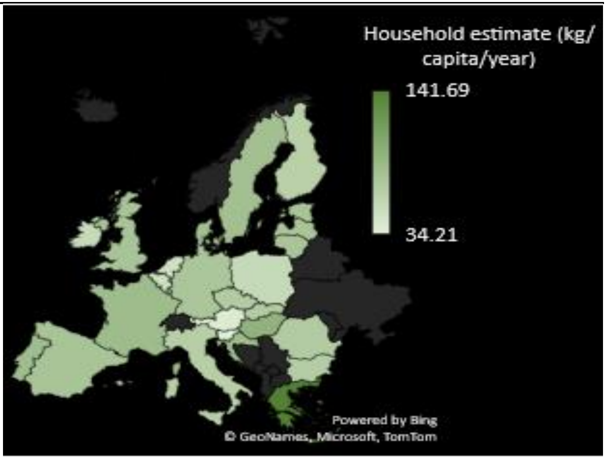
As presented in a 2020 study, the average yearly carelessness across the food supply chain is an important contributor to the yearly 1.3 bn tonnes of wasted food at a global level, while in the EU 28, the costs to cover the 180 kg/capita of food wasted each year, raises up to 25% of the food products that households acquire, revealing a huge monetization and a possible material overturn if this issue of reducing food waste would be properly managed [2].

As in the following part of the study, the United Nations Environment Programme database would be used to drag some EU 28 remarks to reinforce the already mentioned bullet points from the above data analysis. It was stated in the respective study that generated household food waste is similar within a specific country's regions, despite income levels, a remark that diverges from the other conclusion that food waste at the consumer stage is significantly higher in developed countries while developing countries encounter food waste during other different supply chain stages, as production, storage and logistics [42].

It is also important to be reminded that previous food waste estimates have resulted in a different manner (more than double) this time around when looking at the household values, compared to FAO's 2011 value ranges [23].

In Map 1, using UNEP's data, household food estimates clearly overrun the above-mentioned food waste data from Eurostat, indicating that clearly animal and mixed food waste together with vegetal wastes do not include all the facets of food wasted across EU 28.

From this map, one can notice the value sitting around the mean with a couple of countries doubling the average of 75 kg/capita/year across the Union, with 141.69 kg/capita/year (Greece) and 129 kg/capita/year (Malta).




Map 1. EU 28 country food waste estimates by state – households Source: Edited by the authors from UN Environment Programme Food Waste Index Report 2021 [42].

The top 5 minimum wasted amounts are recorded in Ireland, Netherlands, Belgium, Austria, and Slovenia. An aspect that is not overseen in this figure is the total food wasted quantity, measured in tonnes/year, absolute indicator that has Germany in the first place with 6.2 mil tonnes/year, France with 5.5 mil tonnes/year and the UK with 5.2 mil tonnes/year.

Prospecting the food wasted in the services sector of this industry, what can be seen in Map 2 is the fact that on average, around 25 kg/capita/year of food is wasted, highlighting that it equates 30% of the food wasted by households. Ireland comes first in the food services food wasted with almost 60 kg/capita/year while the lowest of the sector is recorded by the UK 16.5 kg/capita/year.

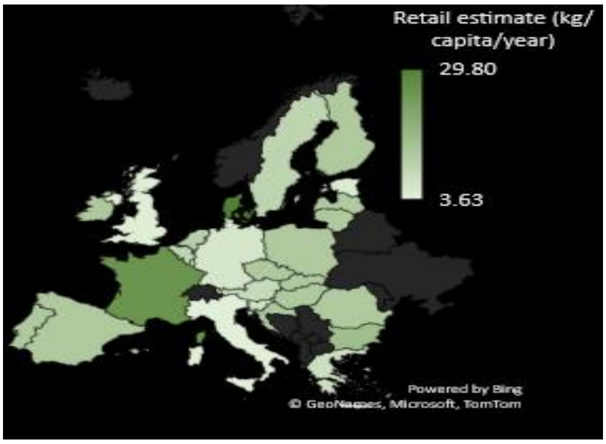

Map 2. EU 28 country food waste estimates by state – food service
Source: Edited by the authors from UN Environment Programme Food Waste Index Report 2021 [42].

In terms of absolute amounts, the same 2 countries sit at the top of the chart, Germany with 1.7 mil tonnes/year generated food waste from the food service sector and France with 1.5 mil tonnes/year.

In the retail sector, food waste records the lowest values across the three sectors mentioned earlier (Map 3), Denmark recording the highest value of food wasted, around 30 kg/capita/year, followed by France (25.6 kg/capita/year) and Bulgaria (15.6 kg/capita/year).

This sector weights 16% on average of the food wasted by households. Quantitatively, France retail sector wastes 1.6 mil tonnes/year, followed by Spain 0.6 mil tonnes/year and Germany 0.5 mil tonnes/year.

When thinking about the need of innovation and research in the food supply chain to reduce the food that is wasted, is obvious that wiser investment in smart technologies could minimize the waste effect and even using these discarded materials in any recycling processes should generate a better anti-food waste promotion scene.




Map 3. EU 28 country food waste estimates by state – retail estimate
Source: Edited by the authors from UN Environment Programme Food Waste Index Report 2021 [42].

Interestingly enough, the researchers have also noted a couple of reasons why the food is still wasted in companies' cases, despite the phenomenon still continuing to exist and even grow, such rationale of keeping food waste levels intact are marked by limited perspectives as [2]: reducing food waste could generate a larger cost than a clear benefit; prolonged investments pay-back; as investments require resources, business priorities don't necessarily have to be towards reducing wasted food; if there is extra food supply, the inexistence of a ready market could further cause wastages by the time the new market is established.

Strategic initiatives target food losses and aim at increasing efforts towards food waste reduction in a direct way while others come as an indirect result of consumers' behavioral change in the long run. Essential supply chain measures such as stock flow and shelf life are mandatory to be implemented to exclude unnecessary loses. Any approach oriented in solving this problem is required to be affordable and specifically applied therefore implementation itself is a fast-paced process mitigating long term profit losses [30].

In the anaerobic digestion process, the food is converted into biogas through bacteriological micro activity, process that generates both thermal and electrical energy offering wide applications in diverse sectors [7]. Different from other food waste elimination methods such as composting or incineration, anaerobic digestion besides the energetical recovery is also causing lesser environmental harm from the resulting greenhouse gases [8].

## CONCLUSIONS

The paper analyzed the food waste worldwide and possible solutions for reducing it. A final answer to the research question is that food waste is related to circular economy, the latter being considered as a solution in fighting food waste. The hypothesis established at the beginning of the research, that food waste quantities have recorded increased numbers has been validated and even academic literature interest over this topic has constantly increased.

Worldwide economic agents will gain competitive advantages if the traditional economic modal would be converted to the circular one, from a consumption-oriented to reintroduction-oriented solutions because of waste reduction, recycling and reusage, implying improved performance indicators such as productivity, unit cost efficiency and profit. Significant production modernization might come at hand when environmental concerns will be introduced in the production function, this will allow the sustainable development across industries and will generate an enhancement in competitiveness, innovation, labor market, social inclusion, and general well-being.

As food waste is generated from farmers to final consumers, composting represents a valid opportunity for economic and productive valorization, the resulted chain piece closes the composting loop. Data is pointing towards increased wasted amounts in households, while businesses stocks' efficiencies signal decreased food discarded. The businesses interest in keeping the consumers' levels up is understandable as a significant reduction in people's own food supplies shelfing would instantly mark reducing shopping frequency, thus decreasing revenues.

Purchasing promos are known to cause households oversupply that effectively result in increased wasted food; therefore, consumers should pay more attention on correctly evaluating family's food products needs to do the food stock replenishment in an efficient manner.

Evaluating wasted food increased trends and adverse forecasts, there could be found some favorable scenarios that could amend consumers' wasted quantities and not impact retailers' outcomes; on one hand any consumer should mind food spends and aim for overall savings just through a slightly better food purchasing habit, storage and usage; and on the other hand get retailers to broaden their business opportunities through implementing discarded food collection through various methods in order to introduce the picked up foods into any valorizing chain towards composting or energetical use.

The new model of consumerism and lifestyle adopted in this decade by the society has a multitude of economic and ecological implications. The minimization of wastage is the primary goal of the globally stated transition to a Circular Economy model, both from a corporate and scientific standpoint. Food waste is extremely significant because, in conjunction to technical and economic factors, it involves social and cultural factors. Wasted food can be reduced, and lost portions can be recovered, which might offer food to vulnerable communities. Also, it can be exploited and used to recover a variety of energy and resources, including biofuels, chemicals, and bioplastics, among many other products.

As natural resources continue to be pressurized due to emerging markets development, population and income growth, the traditional economic model, as previously stated, that is based on consumption, will need to revamp to one that is established on sustainable consumption and production patterns, enabling economic growth without any environmental costs.

Circular economy is ultimately the valid reason to accelerate proper waste management implementation and to close the life cycle loop for each process and their interactions between each other.

The scope of future research could be focusing on food waste reduction methods and what could be effectuated.

Current results are aiming in raising awareness for final consumers on the change importance of both production and consumption patterns.

Increased attention needs to be offered to the environmental side of the economy, an opportunity that needs to be expanded and intensified is the public funding aiming at supporting the circular economy.

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# VEGETATIVE PROPAGATION IN JADE TREE USING ROOTING BIOSTIMULATORS OF STEM CUTTINGS

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***Abstract***

*The present study analyzed the influence of some bioactive substances on vegetative propagation based on stem cuttings of Crassula ovata (Miller) Druce (jade tree). Stem cuttings were taken from the source plants for vegetation propagation. The cuttings were 5 cm long, 0.6 cm in diameter and had two pairs of leaves, with a high degree of uniformity. Three biostimulant products were used, Raiza, Rhyzo and Sangral, along with a control variant (Ct). A peat substrate, Klasmann TS3, was used for rooting. The cuttings treated with the biostimulating products and those from the control variant were placed on the rooting substrate on June 16, 2022. The number of roots (RN) and the length of roots (RL) were evaluated at three times during the study period; June 30 (t1), July 7 (t2) and July 14 (t3). The variation of RN and RL in relation to time (days) during the study period was described by polynomial equations of the 2nd degree, under statistical safety conditions (p<0.01). According to PCA, PC1 explained 60.665% of variance, and PC2 explained 26.216% of variance. Associated with the Sangral product were RN-t2 and RN-t3 parameters, and associated with the Raiza and Rhyzo products were RN-t1 parameters and especially root length, RL-t1, RL-t2 and RL-t3. Under the aspect of the increase in the formation of the number of roots, based on the recorded values, it was found that the Sangral product generated a stronger rooting (RN-t2-I = 4.92; RN-t3-I = 3.25), and with regard to the length of the roots (RL), the Rhyzo product generated the largest increases (RL-t2-I = 1.03 cm, respectively RN-t3-I = 1.49 cm).*

**Key words:** *Crassula ovata, jade tree, rooting biostimulators, stem cuttings, vegetative propagation*

## INTRODUCTION

*Crassula ovata* (Miller) Druce, is part of the *Crassulaceae* Family, is native to South Africa and Mozambique, and as an ornamental apartment plant (indoor spaces) is used throughout the world [2, 31]. *Crassula ovata* is a plant known under different popular or common names, such as "jade tree", "friendship tree", "money tree", etc.

*Crassula ovata* is a perennial, succulent plant with many branches, with a bushy appearance. The stems are thick, branched, fleshy, and juicy, up to 30-45 cm high. The leaves are oval-rounded, waxy, juicy, positioned opposite each other on the stems, dark green. The flowers appear very rarely, especially in plants grown ornamentally indoors and are positioned on the top of the white or light pink flower stalks [26].

*Crassula ovata* is cultivated as an ornamental plant through its leaves. In very bright spaces, the color of the leaves takes on a reddish tint. Although light is important for *Crassula ovata* it is recommended to avoid intense light in the midday hours [12]. In the conditions of our country (temperate continental climate), the plants are kept in the conditions of the cold season (autumn / winter) indoors, and in the spring / summer season the plants can be placed in open spaces (gardens, parks).

*Crassula ovata* plants are sensitive to some pathogenic and harmful species (eg *Botrytis* sp., *Fusarium oxysporum*, woolly louse) [9, 28].

In the natural conditions (native area), *Crassula ovata* is a component of thicket vegetation, with mixed vegetation, on rocky and dry hilly areas, and shows certain adaptations to the surface of the leaves with a role in the utilization of water from atmospheric humidity [2, 13, 16].

Substrates with a light texture (peat or peat and sand), well-drained [25], represent suitable growing and growing environments for *Crassula ovata*.

Different species of Crassula, including *Crassula ovata*, have been studied in relation to certain adaptations to water availability and regime [13]. CAM-type metabolism facilitates *C. ovata* to reduce water losses from the leaves, without limiting the photosynthesis process [17].

Some studies have evaluated utilities in the pharmaceutical field and the antimicrobial and phytochemical activity of the *Crassula ovata* species was studied on different strains of bacteria [18, 22].

Propagation of *Crassula ovata* plants can be done by techniques specific to the group of succulent ornamental plants (*Crassulaceae*), by leaf or stem cuttings, based on the principles of vegetative propagation, or by "*in vitro*" propagation [1, 3, 21].

The propagation of *Crassula ovata* by leaf cuttings was studied in relation to different bioactive substances influences [7].

The study evaluated the vegetative propagation by stem cuttings in *Crassula ovata*, under the influence of three rooting biostimulator products.

## MATERIALS AND METHODS

Vegetative propagation in jad tree, *Crassula ovata* species, was studied by stem cuttings technique, under the influence of three rooting biostimulators. Uniform cuttings, 5 cm long, 0.6 cm in diameter, with two pairs of leaves were taken from the source plants, Figure 1.

A propagation variant without cuttings treatments (control, Ct) and three variants with cuttings treated with biostimulating substances for the rooting process were considered. 20 cuttings were used for each experimental variant, in three repetitions.

Photo 1. Source plants, *Crassula ovata* species
Source: original picture, photo of the authors.

The biostimulating products were used: Raiza (Raiza-Mix), Rhyzo and Sangral.

Raiza is a rooting biostimulator, based on a liquid formula containing amino acids (12%), nutrients (N, B, Cu, Fe, Mn, Mo, Zn), phytohormones of natural origin and other bioactive substances (the bioactive substances come from from extracts of *Ascophyllum nodosum* algae). The product is certified for organic agriculture. Rhyzo is a product with a biostimulating role of the rooting process, packaged in powder form. In the active composition it has free amino acids (58.0%), nitrogen (9.8%), phosphorus (5.0%), and rooting bio-inducers (1.9%). Sangral is a product with a biostimulating rooting role, packaged in powder form.

The cuttings from the control variant and those treated with biostimulating substances (figure 2) were rooted in uniform conditions, on Klasmann TS3 peat substrate [34].

Photo 2. Example of a cutting used for vegetative propagation, *Crassula ovata*
Source: original picture, photo of the authors.

The peat substrate presented an extra fine structure (0 – 5.00 mm granulation), slightly acidic reaction (pH=6.00, $H_2O$, v/v 1:2.5), with a supplement of nitrogen nutrients (140 mg N/l), phosphorus (100 mg $P_2O_5$/l), potassium (180 mg $K_2O$/l), magnesium (100 mg Mg/l), trace elements (chelated iron, EDTA).

The cuttings treated with the control variant (Ct) were placed on the rooting substrate on June 16, 2022.

In order to evaluate the influence of the applied treatments on the rooting process, within the vegetative propagation of the *Crassula ovata* species, determinations were made regarding the number of roots (RN) and root length (RL) at three moments during the study period; June 30 (t1), July 7 (t2) and July 14 (t3).

The experimental data recorded regarding RN and RL on the experimental variants were statistically analyzed by appropriate methods. The standard error (SE) was calculated on the data set related to the determination moments (t1 to t3).

Regression analysis was used to find out the variation of rooting parameters (RN, RL) in relation to time on each experimental variant. PCA analysis (correlation), in which the level of explanation of the variance based on PC1 and PC2 was evaluated.

The increase generated by the treatments applied in the rooting process (RN, RL) was calculated in relation to the control variant.

For data processing and graphic representations, the calculation module in EXCEL and the PAST software were used [10].

## RESULTS AND DISCUSSIONS

Vegetative propagation by stem cuttings in the *Crassula ovata* species was analyzed through the prism of treatments with biostimulating substances applied to the cuttings, compared with the control variant. The rooting process was evaluated through the prism of two representative indicators, the number of roots formed and the length of the roots at different moments of time, during the study period.

Although the stem or leaf cuttings of the species under study have the ability to emit roots naturally, without stimulating treatments, it is desirable to obtain a high rate of propagation, with vigorous plants, through the propagation process.

The values recorded for the rooting process (RN, RL) on the experimental variants are presented in Table 1 and Table 2.

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Table 1. Root number (RN) values in relations to rooting biostimulators, *Crassula ovata*

| Experimental variants | RN -t1 | RN -t2 | RN -t3 |
|---|---|---|---|
| Control (Ct) | 0 | 6.33 | 7.88 |
| Raiza | 3.40 | 9.60 | 8.50 |
| Rhyzo | 2.33 | 8.60 | 9.30 |
| Sangral | 1.00 | 11.25 | 11.13 |
| SE | ±0.69 | ±1.02 | ±0.7 |

Source: original data, obtained from experiment.

Table 2. Root length (RL) values in relations to rooting biostimulators, *Crassula ovata*

| Experimental variants | RL -t1 | RL -t2 | RL -t3 |
|---|---|---|---|
| Control (Ct) | 0 | 1.07 | 2.16 |
| Raiza | 0.28 | 1.40 | 2.57 |
| Rhyzo | 0.47 | 2.10 | 3.65 |
| Sangral | 0.20 | 1.30 | 2.79 |
| SE | ±0.08 | ±0.22 | ±0.31 |

Source: original data from experiment.

The variation of the number of roots (RN) and the length of roots (RN) in the biological material for vegetative propagation was analyzed during the study period, under the influence of the three biostimulating substances used.
The variation of RN and RL, in relation to time (days), during the study period, was described by polynomial equations of 2nd degree, in conditions of statistical safety ($p<0.01$), and with graphic representation in Figure 1, for RN parameter, and in Figure 2 for RL parameter, respectively.

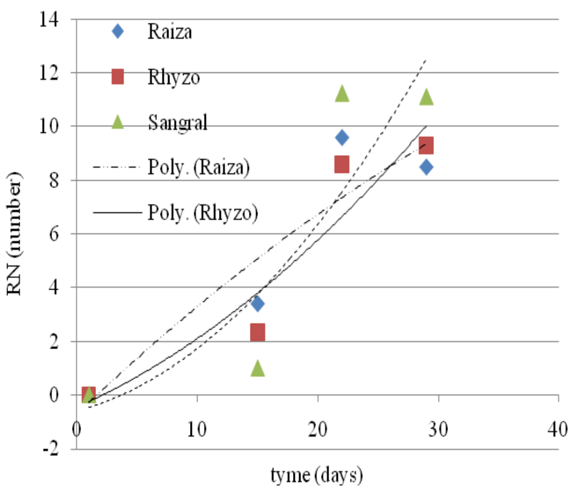

Fig. 1. Graphical representation of RN parameter in relation to time (t, days), under the rooting biostimulators influence, *Crassula ovata*
Source: Original graph, based on experimental data.

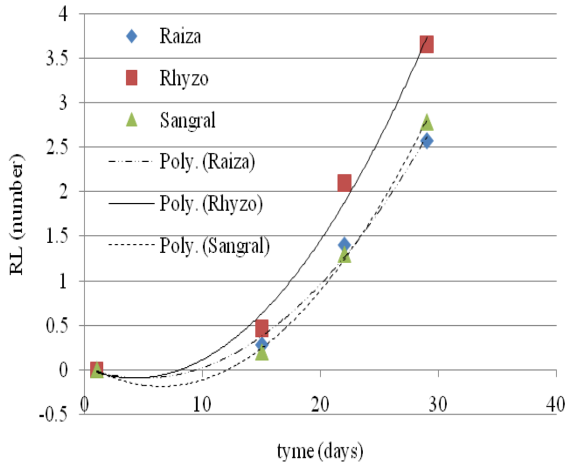

Fig. 2. Graphical representation of RL parameter in relation to time (t, days) under the rooting biostimulators influence, *Crassula ovata*
Source: Original graph based on experimental data.

Based on PCA, the diagram in Figure 3 was obtained, which includes the variants distribution, in relation to the registered effect on the rooting parameters (RN and RL) studied. The control variant (Ct) was placed on independent position in relations to studied parameters (RN, RL), as biplot.

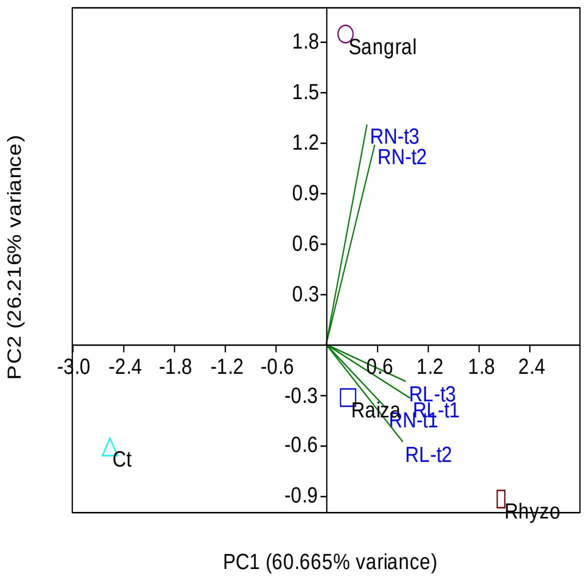

Fig. 3. PCA diagram, as regard the distribution of variants in relation to rooting parameters, *Crassula ovata*
Source: Original graph based on experimental data.

Associated with the Sangral product was parameters RN-t2 and RN-t3. This confirms the fact that the number of roots was more strongly influenced by the Sangral product. Associated with Raiza and Rhyzo products were associated parameters RN-t1, and especially root length, RL-t1, RL-t2 and RL-t3. This confirms the fact that the two products had a stronger effect on the growth in the length of the roots. PC1 explained 60.665% of variance, and PC2 explained 26.216% of variance. The increase (I) recorded in the rooting process (RN, RL), generated by the treatments applied to *Crassula ovata* cuttings, compared to the control variant, was calculated. The values recorded at the t2 and t3 moments of determination were taken into account. In terms of the number of roots, based on the recorded values, it was found that the Sangral product generated stronger rooting (RN-t2-I = 4.92; RN-t3-I = 3.25) compared to the other two products tested. The Raiza product generated intermediate values for RN at time t2 (RN-t2-I = 3.27) and lower values at time t3 (RN-t2-I = 0.63). The Rhyzo product generated values of RN at the level of RN-t2-I = 2.27 in moment t2, respectively RN-t3-I = 1.43 in moment t3. With regard to root length (RL), the Rhyzo product generated the greatest growth (RL-t2-I = 1.03 cm, respectively RN-t3-I = 1.49 cm). The graphic distribution of the growth of the two rooting parameters under the influence of the three biostimulators tested is presented in Figure 4. Samples of the rooted cuttings, at the t3 determination moment, in relation to biostimulators tested, are shown in Figure 5.

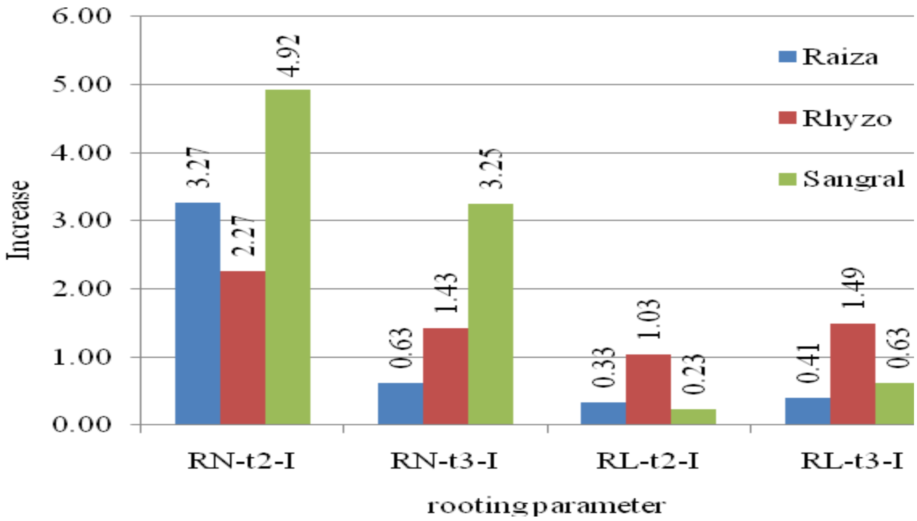


Fig.4. Graphic representation of increase (I) for studied parameters, in relation to the tested biostimulators, *Crassula ovata* species
Source: Original graph, based on calculated data.

Fig. 5. Sample of the rooted cuttings, in relation to tested biostimulators; Raiza (left), Rhyzo (middle), Sangral (right), *Crassula ovata*
Source: original picture, photos of the authors

The business with ornamental plants (propagation, growth, and marketing) can contribute to supplementing income for different categories and socio-economic conditions [20].

For an adequate management, knowledge regarding the eco-physiological requirements of plants, growing technologies, but also information regarding cost-benefit analyzes are necessary [20].

In the context of the conditions in urban habitats and ecosystems, highlighted by specific indices in certain studies [5, 11], plants tolerant to water stress, with good utilization of limited water resources (eg *Crassula ovata*, but also others), can represent an alternative in certain arrangements and ornamental structures in open spaces [23, 29].

Growing technologies and new genotypes bring improvements in the cultivation of ornamental plants, but at the same time there are different challenges regarding the market, production costs, changing environmental factors, the risk of stress factors or attack by new or old diseases and pests [4].

Regarding the propagation of ornamental plants (generative and vegetative), methods based on vegetative propagation have been developed and perfected that facilitate obtaining quality biological material, with genetic characteristics identical to the "source plant" [24]. Different bioactive substances with the role of stimulating the rooting process have been synthesized and tested in various species and groups of ornamental plants, propagation and growth conditions, so that the selection and use of appropriate products is easy for vegetative propagation [8, 15, 30]. At the same time, different types of substrates for rooting and plant growth were studied and tested, in relation to different species of horticultural plants, by stages in the reproduction process and plant age categories [14, 25, 32, 33]. Imaging plant analysis techniques facilitate the rapid estimation of possible pathogenic effects, with prompt interventions (detachment of affected leaves, local treatments etc.), without affecting the overall ornamental appearance of the respective plants [6]. The vegetative propagation of some ornamental plants (the jade tree, in this study) for commercial purposes, can be an alternative for supplementing sources of income, against the background of the socio-economic problems of the last period (associated with Covid 19, the post-Covid period, the energy crisis, etc.). Studies on the feasibility of business with ornamental plants during the Covid pandemic highlighted the feasibility of such businesses (with ornamental plants) in a certain socio-economic context [19, 27]. Besides the fact that it is a relaxing activity, the business with ornamental plants can train different age categories (eg children, elderly people), it can be done outside of a basic work schedule (as a complementary activity), so the benefits can be multiple.

## CONCLUSIONS

In the process of vegetative propagation in the species *Crassula ovata*, the stem cuttings responded differently to the action of the treatments with the tested bioactive products. The Sangral product strongly influenced the number of roots of the stem cuttings (RN-t2-I = 4.92; RN-t3-I = 3.25) compared to the other two products tested. In terms of root length (RL), the Rhyzo product had a stronger effect (RL-t2-I = 1.03 cm, respectively RN-t3-I = 1.49 cm), compared to the other products.

The Raiza product generated intermediate values for RN at time t2 (RN-t2-I = 3.27) and lower values at time t3 (RN-t2-I = 0.63).

Each biostimulator product tested generated better values in the rooting process of the cuttings, compared to the control variant. The associated use of the products, in the interest of the roots number stimulating (Sangral), and the roots length (Rhyzo), can be a better option for obtaining vigorous plants in the process of vegetative reproduction in the *Crassula ovata* species.

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# FORECASTING THE VALUE OF THE EXPORT OF UKRAINIAN AGRICULTURAL PRODUCTS BASED ON FUZZY SETS

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***Abstract***

*Ukraine has a significant export potential of agricultural products. Ukraine's acquisition of the status of a candidate for EU membership and the desire to take a worthy position in the global agro-food markets necessitates a permanent monitoring and forecasting of the value of Ukrainian exports of agricultural products. The actual data of the State Statistics Service of Ukraine for 2014–2021 regarding the commodity structure of foreign trade in agricultural products of Ukraine were used for the analysis. It was determined that the following types of goods had the greatest export potential (over USD 100 million annually): 02 meat and meat preparations; 04 milk and milk products; eggs; honey; 08 eatable fruits and nuts; 10 cereals; 11 flour-grinding products; 12 oil seeds and fruits; 15 animal or plant fats and oils. At the same time, the following types of goods had the lowest export potential (less than USD 10 million annually): 06 seedlings and other trees; 13 shellac natural. In the analyzed period, all types of goods (except 04 milk and milk products; eggs; honey; 14 plant materials for producing) had positive dynamics of most or half of export indicators. For each of the 15 types of agricultural products, forecast indicators of the value of exports for 2022 are constructed according to the author's methodology in the form of trapezoidal fuzzy intervals, where optimistic and pessimistic estimates are calculated on the basis of actual data, taking into account average growth rates.*

**Key words:** *export value, agricultural products, Ukraine, fuzzy sets, forecasting*

## INTRODUCTION

Ukraine is an agrarian country with great export potential of agro-industrial products. This is facilitated, on the one hand, by fertile soils (product quality, yield), and on the other hand, by a favorable location in the middle of Europe (convenient logistics). Ukraine is among the twenty largest trading partners of the EU in terms of trade in food products, beverages and tobacco products [1]. In the context of international research and Ukraine's acquisition of the status of a candidate for EU membership, it is expedient to analyze and forecast the cost of exporting agricultural products of Ukraine to world markets. Various aspects of export operations with products of the agro-industrial complex of Ukraine were studied by the following scientists: Fediv R. and Fediv I. (2020) – the main trends in the formation and implementation of the export potential of agricultural enterprises [2]; Koliadenko S. *et al.* (2020) – the state and prospective directions of Ukrainian export of agricultural products, including forecasting using the method of mathematical modeling of a continuous system of aperiodic components [4]; Kryukova I. O. *et al.* (2018) – level of competitiveness of agricultural and food products, possible directions of export development [5]; Kvasha S. *et al.* (2019) – possible ways of illegally withdrawing profits abroad, in particular through export trade in agricultural products [6]; Levkovskyy E. (2019) – progressive gains in the export of agri-food products related to environmental requirements (on the example of key players in the global agricultural market) [7]; Matyushenko I. Y. *et al.* (2018) – the state and prospects for the development of Ukraine's foreign trade in products of the agro-industrial complex in the context of European integration and global challenges [8]; Melnyk T. *et al.* (2021) – factors of formation and implementation of the export potential of the agro-industrial complex of Ukraine, the place of Ukrainian products on the world food market [9]; Nagyova L. *et al.* (2018) – trends in export trade of Ukraine with the countries of the Visegrad Group [10]; Parkhomenko N. *et al.* (2022) – the state of the agricultural sector of Ukraine, development directions and prospects, export opportunities and export potential [11]; Polkovnichenko S. O. and Rosokhach O. V. (2016) – dynamics, commodity and geographical structure of export of agricultural products of domestic producers [12]; Voronych M. (2019) – the state and dynamics of foreign trade in the agricultural sector, the advantages of the domestic agricultural sector on world agricultural markets [13]; Shkolnyi O. O. *et al.* (2019) – the current level of competitiveness of the domestic agro-food sector in the context of foreign economic activity, the possibility of attracting regulatory mechanisms to increase the country's exports [14]. Ukraine's desire to join the EU and take a decent position in the global agri-food markets necessitates permanent monitoring and forecasting of the value of Ukrainian exports of agricultural products.

## MATERIALS AND METHODS

The actual data of the State Statistics Service of Ukraine for 2014–2021 on the commodity structure of foreign trade in agricultural products of Ukraine (without taking into account the temporarily occupied territory of the Autonomous Republic of Crimea, the city of Sevastopol, and the temporarily occupied territories in the Donetsk and Luhansk regions) were used for the analysis [15].

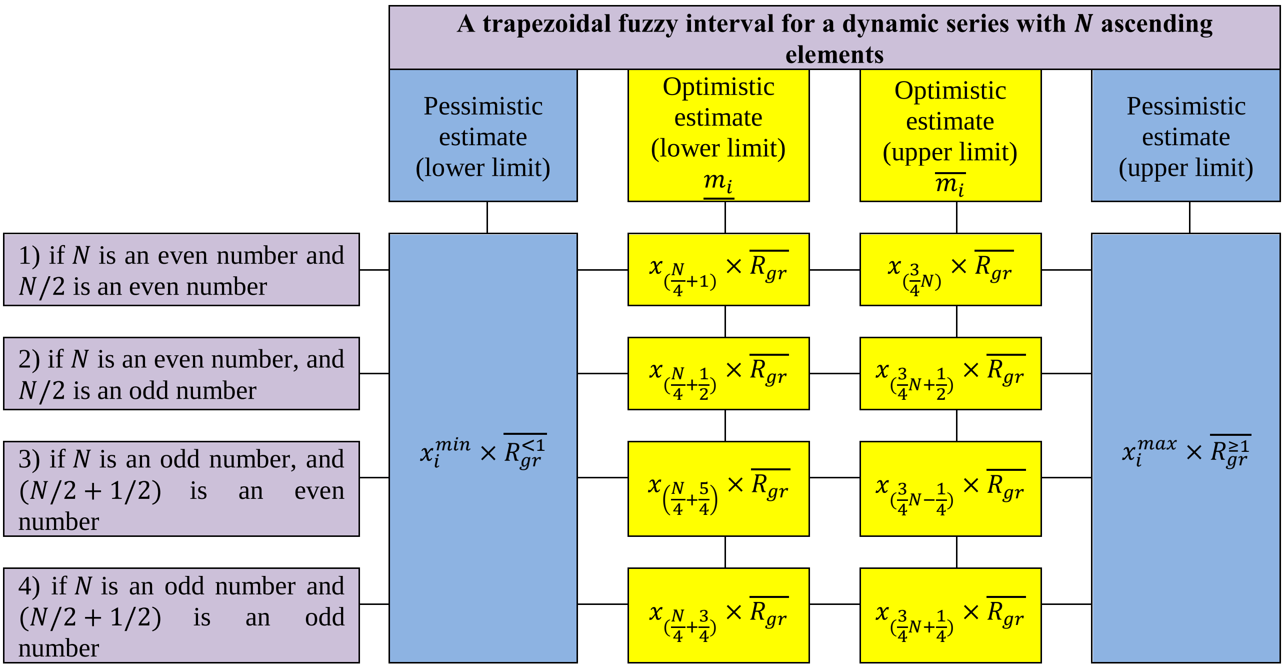


Fig.1. Algorithm for determining the limits of a trapezoidal fuzzy interval.
Source: Author's development [16].

For forecasting, the theory of fuzzy sets was used, in particular, trapezoidal fuzzy intervals of the following form were constructed:

$$indicator_i = (\underline{m_i};\ \overline{m_i};\ a_i;\ b_i), \quad (1)$$

where: $\underline{m_i}$ – is the lower value of the optimistic (with the greatest measure of belonging $\mu A(x) = 1$) estimate of indicator $i$;

$\overline{m_i}$ – is the upper value of the optimistic estimate of indicator $i$;

$a_i$ – is the difference between the lower limits of optimistic and pessimistic (with the smallest measure of belonging $\mu A(x) = 0$) estimates of indicator $i$;

$b_i$ – is the difference between the upper limits of pessimistic and optimistic estimates of indicator $i$.

The author's methodology was used to determine pessimistic and optimistic estimates. It is shown in Fig. 1.

According to it, the lower and upper limits of the pessimistic estimate of the forecast indicators will be defined as the smallest ($x_i^{min}$) and the largest ($x_i^{max}$) value of the export indicators of agricultural products of Ukraine for the analyzed period, adjusted for the arithmetic mean value of chain growth rates less than 1 ($\overline{R_{gr}^{<1}}$) and greater than or equal to 1 ($\overline{R_{gr}^{\geq 1}}$), respectively.

The optimistic interval (the lower and upper limits of the optimistic estimate of forecast indicators) corresponds to the «golden mean» of the dynamic series ordered by growth, adjusted for the average arithmetic value of all chain growth rates ($\overline{R_{gr}}$).

That is, in our opinion, the optimistic interval includes approximately half of the central elements of the dynamic series ordered by growth; they have the highest probability of verification (measure of belonging). Note that the average growth rates were calculated using the formula of the arithmetic average, not the geometric average, in order to avoid significant miscalculations in the event of significant fluctuations in the series. It should be noted that Gerasymchuk O. B. (2009) determined forecast estimates of the export-import activity of Ukraine based on the principles of the fuzzy game model [3].

## RESULTS AND DISCUSSIONS

The commodity structure of Ukraine's export operations for 2014–2021 in terms of the main agricultural products is shown in Table 1.

Table 1. Commodity structure of foreign trade in agricultural products of Ukraine (exports), thsd. USD

| Commodity code and title by Ukrainian Classification of Commodities in Foreign Trade (UC CFT) | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|
| 01 live animals | 14,471.8 | 25,639.9 | 30,903.4 | 45,708.8 | 45,786.6 | 62,547.7 | 51,506.9 | 40,878.5 |
| 02 meat and meat preparations | 381,775.3 | 377,668.3 | 387,791.9 | 531,240.1 | 645,982.3 | 711,895.1 | 652,106.9 | 845,553.4 |
| 03 fish and crustacea | 27,401.3 | 12,994.8 | 17,007.3 | 26,376.9 | 24,981.4 | 33,637.5 | 42,204.0 | 57,194.7 |
| 04 milk and milk products; eggs; honey | 575,431.0 | 386,477.3 | 330,521.4 | 494,207.3 | 480,947.4 | 453,877.2 | 426,541.7 | 378,473.9 |
| 05 other animal products | 15,394.5 | 20,654.6 | 8,812.9 | 11,224.0 | 12,940.6 | 15,058.3 | 15,805.2 | 23,094.4 |
| 06 seedings and other trees | 1,414.4 | 2,340.4 | 3,703.8 | 3,956.6 | 4,442.8 | 6,479.7 | 5,742.6 | 8,142.6 |
| 07 vegetables | 129,861.6 | 97,214.6 | 152,647.3 | 235,369.3 | 235,682.7 | 184,515.0 | 168,147.4 | 196,607.0 |
| 08 eatable fruits and nuts | 148,191.4 | 154,083.5 | 148,221.9 | 195,287.3 | 228,564.1 | 260,112.2 | 238,390.2 | 368,197.5 |
| 09 coffee, tea | 14,645.0 | 10,595.7 | 14,088.4 | 13,610.0 | 12,059.2 | 11,709.0 | 15,011.2 | 15,900.9 |
| 10 cereals | 6,544,127.6 | 6,057,490.0 | 6,073,915.3 | 6,501,134.3 | 7,240,558.1 | 9,633,333.9 | 9,410,668.9 | 12,343,846.1 |
| 11 flour-grinding products | 124,400.7 | 117,887.9 | 138,667.9 | 181,891.4 | 175,811.2 | 202,099.4 | 154,490.8 | 148,284.1 |
| 12 oil seeds and fruits | 1,687,715.3 | 1,475,455.6 | 1,534,995.1 | 2,060,121.4 | 1,954,149.8 | 2,563,242.3 | 1,842,430.9 | 2,435,156.5 |
| 13 shellac natural | 557.1 | 527.0 | 443.3 | 587.5 | 1,090.7 | 818.5 | 944.1 | 3,606.9 |
| 14 plant materials for producing | 85,226.1 | 55,897.8 | 27,010.8 | 23,750.2 | 33,701.9 | 52,233.1 | 47,412.0 | 18,286.7 |
| 15 animal or plant fats and oils | 3,822,031.8 | 3,299,799.1 | 3,962,975.8 | 4,605,666.2 | 4,496,511.0 | 4,732,237.5 | 5,746,921.7 | 7,037,234.2 |

Source: Data from the State Statistics Service of Ukraine [17].

As we can see, in the analyzed period, the highest value of export operations (over 100 million USD annually) was observed for such types of goods as 02 meat and meat preparations; 04 milk and milk products; eggs; honey; 08 eatable fruits and nuts; 10 cereals; 11 flour-grinding products; 12 oil seeds and fruits; 15 animal or plant fats and oils.

The lowest value of export operations (less than 10 million USD annually) was observed for such types of goods as 06 seedlings and other trees; 13 shellac natural.

Chain growth rates of export indicators, as well as their average values, necessary for the calculation of trapezoidal fuzzy intervals, are shown in Table 2.

Table 2. Chain growth rates of agricultural exports of Ukraine

| Commodity code and title by UC CFT | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | The average value of indicators | The average value of indicators which >1 | The average value of indicators which <1 |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 live animals | 1.77 | 1.21 | 1.48 | 1.00 | 1.37 | 0.82 | 0.79 | 1.21 | 1.36 | 0.81 |
| 02 meat and meat preparations | 0.99 | 1.03 | 1.37 | 1.22 | 1.10 | 0.92 | 1.30 | 1.13 | 1.20 | 0.95 |
| 03 fish and crustacea | 0.47 | 1.31 | 1.55 | 0.95 | 1.35 | 1.25 | 1.36 | 1.18 | 1.36 | 0.71 |
| 04 milk and milk products; eggs; honey | 0.67 | 0.86 | 1.50 | 0.97 | 0.94 | 0.94 | 0.89 | 0.97 | 1.50 | 0.88 |
| 05 other animal products | 1.34 | 0.43 | 1.27 | 1.15 | 1.16 | 1.05 | 1.46 | 1.12 | 1.24 | 0.43 |
| 06 seedings and other trees | 1.65 | 1.58 | 1.07 | 1.12 | 1.46 | 0.89 | 1.42 | 1.31 | 1.38 | 0.89 |
| 07 vegetables | 0.75 | 1.57 | 1.54 | 1.00 | 0.78 | 0.91 | 1.17 | 1.10 | 1.32 | 0.81 |
| 08 eatable fruits and nuts | 1.04 | 0.96 | 1.32 | 1.17 | 1.14 | 0.92 | 1.54 | 1.16 | 1.24 | 0.94 |
| 09 coffee, tea | 0.72 | 1.33 | 0.97 | 0.89 | 0.97 | 1.28 | 1.06 | 1.03 | 1.22 | 0.89 |
| 10 cereals | 0.93 | 1.00 | 1.07 | 1.11 | 1.33 | 0.98 | 1.31 | 1.10 | 1.17 | 0.95 |
| 11 flour-grinding products | 0.95 | 1.18 | 1.31 | 0.97 | 1.15 | 0.76 | 0.96 | 1.04 | 1.21 | 0.91 |
| 12 oil seeds and fruits | 0.87 | 1.04 | 1.34 | 0.95 | 1.31 | 0.72 | 1.32 | 1.08 | 1.25 | 0.85 |
| 13 shellac natural | 0.95 | 0.84 | 1.33 | 1.86 | 0.75 | 1.15 | 3.82 | 1.53 | 2.04 | 0.85 |
| 14 plant materials for producing | 0.66 | 0.48 | 0.88 | 1.42 | 1.55 | 0.91 | 0.39 | 0.90 | 1.48 | 0.66 |
| 15 animal or plant fats and oils | 0.86 | 1.20 | 1.16 | 0.98 | 1.05 | 1.21 | 1.22 | 1.10 | 1.17 | 0.92 |

Source: Author's calculation based on data from Table 1.

Note that in Table 2, for better data visualization, annual values of indicators greater than 1 are highlighted in blue, less than 1 in yellow.

As we can see, in the analyzed period, for 13 out of 15 types of goods (except for 04 milk and milk products; eggs; honey; 14 plant materials for producing) the average value of chain growth rates was >1, which proves the positive dynamics of most or half of the indicators export of agricultural products. We should especially note such a product as 13 shellac natural, which reached in 2021 a record mark of chain growth rates of 3.82.

Table 3 shows the dynamic series of exports of goods ordered by growth.

Table 3. Dynamic series of agricultural export indicators of Ukraine for 2014–2021, ordered by growth

| Commodity code and title by UC CFT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 01 live animals | 14,471.8 | 25,639.9 | 30,903.4 | 40,878.5 | 45,708.8 | 45,786.6 | 51,506.9 | 62,547.7 |
| 02 meat and meat preparations | 377,668.3 | 381,775.3 | 387,791.9 | 531,240.1 | 645,982.3 | 652,106.9 | 711,895.1 | 845,553.4 |
| 03 fish and crustacea | 12,994.8 | 17,007.3 | 24,981.4 | 26,376.9 | 27,401.3 | 33,637.5 | 42,204.0 | 57,194.7 |
| 04 milk and milk products; eggs; honey | 330,521.4 | 378,473.9 | 386,477.3 | 426,541.7 | 453,877.2 | 480,947.4 | 494,207.3 | 575,431.0 |
| 05 other animal products | 8,812.9 | 11,224.0 | 12,940.6 | 15,058.3 | 15,394.5 | 15,805.2 | 20,654.6 | 23,094.4 |
| 06 seedings and other trees | 1,414.4 | 2,340.4 | 3,703.8 | 3,956.6 | 4,442.8 | 5,742.6 | 6,479.7 | 8,142.6 |
| 07 vegetables | 97,214.6 | 129,861.6 | 152,647.3 | 168,147.4 | 184,515.0 | 196,607.0 | 235,369.3 | 235,682.7 |
| 08 eatable fruits and nuts | 148,191.4 | 148,221.9 | 154,083.5 | 195,287.3 | 228,564.1 | 238,390.2 | 260,112.2 | 368,197.5 |
| 09 coffee, tea | 10,595.7 | 11,709.0 | 12,059.2 | 13,610.0 | 14,088.4 | 14,645.0 | 15,011.2 | 15,900.9 |
| 10 cereals | 6,057,490.0 | 6,073,915.3 | 6,501,134.3 | 6,544,127.6 | 7,240,558.1 | 9,410,668.9 | 9,633,333.9 | 12,343,846.1 |
| 11 flour-grinding products | 117,887.9 | 124,400.7 | 138,667.9 | 148,284.1 | 154,490.8 | 175,811.2 | 181,891.4 | 202,099.4 |
| 12 oil seeds and fruits | 1,475,455.6 | 1,534,995.1 | 1,687,715.3 | 1,842,430.9 | 1,954,149.8 | 2,060,121.4 | 2,435,156.5 | 2,563,242.3 |
| 13 shellac natural | 443.3 | 527.0 | 557.1 | 587.5 | 818.5 | 944.1 | 1,090.7 | 3,606.9 |
| 14 plant materials for producing | 18,286.7 | 23,750.2 | 27,010.8 | 33,701.9 | 47,412.0 | 52,233.1 | 55,897.8 | 85,226.1 |
| 15 animal or plant fats and oils | 3,299,799.1 | 3,822,031.8 | 3,962,975.8 | 4,496,511.0 | 4,605,666.2 | 4,732,237.5 | 5,746,921.7 | 7,037,234.2 |

Source: Author's calculation based on data from Table 1.

In our case, the number of members of the dynamic series $N = 8$ is an even number, and the value $N/2 = 8/2 = 4$ is also an even number, therefore, according to Fig. 1, the 1st and 8th terms of the series will be used to calculate the lower and upper limits of the pessimistic estimate of forecast indicators; the 3rd $(\frac{N}{4} + 1 = 3)$ and 6th $(\frac{3}{4}N = 6)$ terms of the series will be used to calculate the lower and upper limits of the optimistic estimate. They are highlighted in different colors in Table 3.

Therefore, the fuzzy intervals for the export of agricultural products of Ukraine for 2022 will have the form of the following four elements:

**01 live animals:**

$product_{01} = (37{,}265.0;\ 55{,}212.0;\ 25{,}563.6;\ 30{,}151.4);$

**02 meat and meat preparations:**

$product_{02} =$
$(438{,}573.0;\ 737{,}500.0;\ 78{,}795.3;\ 279{,}090.0);$

**03 fish and crustacea:**

$product_{03} = (29{,}397.4;\ 39{,}583.6;\ 20{,}162.4;\ 38{,}384.9);$

**04 milk and milk products; eggs; honey:**

$product_{04} =$
$(373{,}560.5;\ 464{,}873.3;\ 83{,}207.8;\ 395{,}531.5);$

**05 other animal products:**

$product_{05} = (14{,}547.7;\ 17{,}768.1;\ 10{,}787.4;\ 10{,}879.2);$

**06 seedlings and other trees:**

$product_{06} = (4{,}863.1;\ 7{,}540.1;\ 3{,}609.6;\ 3{,}730.4);$

**07 vegetables:**

$product_{07} = (168{,}468.2;\ 216{,}984.0;\ 89{,}309.8;\ 94{,}276.9);$

**08 eatable fruits and nuts:**

$product_{08} =$
$(178{,}047.5;\ 275{,}466.1;\ 38{,}862.6;\ 181{,}852.5);$

**09 coffee, tea:**

$product_{09} = (12{,}433.9;\ 15{,}100.0;\ 3{,}039.3;\ 4{,}357.0);$

**10 cereals:**

$product_{10} =$
$(7{,}180{,}469.6;\ 10{,}394{,}035.6;\ 1{,}418{,}211.1;\ 3{,}996{,}273.8);$

**11 flour-grinding products:**

$product_{11} = (144{,}134.8;\ 182{,}742.5;\ 36{,}901.8;\ 62{,}302.9);$

**12 oil seeds and fruits:**

$product_{12} =$
$(1{,}822{,}115.0;\ 2{,}224{,}177.3;\ 572{,}117.8;\ 990{,}036.6);$

**13 shellac natural:**

$product_{13} = (851.0;\ 1{,}442.2;\ 476.1;\ 5{,}911.9);$

**14 plant materials for producing:**

$product_{14} = (24{,}235.1;\ 46{,}865.4;\ 12{,}122.8;\ 79{,}647.3);$

**15 animal or plant fats and oils:**

$product_{15} =$
$(4{,}355{,}976.8;\ 5{,}201{,}524.8;\ 1{,}320{,}718.8;\ 3{,}038{,}393.6).$

Graphically, trapezoidal fuzzy intervals of forecast indicators of the value of exports of agricultural products of Ukraine for 2022 are shown in Figures 2–16.

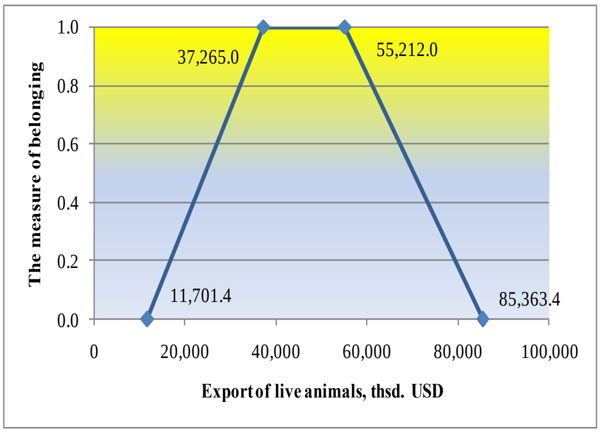


Fig. 2. Trapezoidal fuzzy interval for product 01 live animals.
Source: Constructed by the author based on Tables 2 and 3.

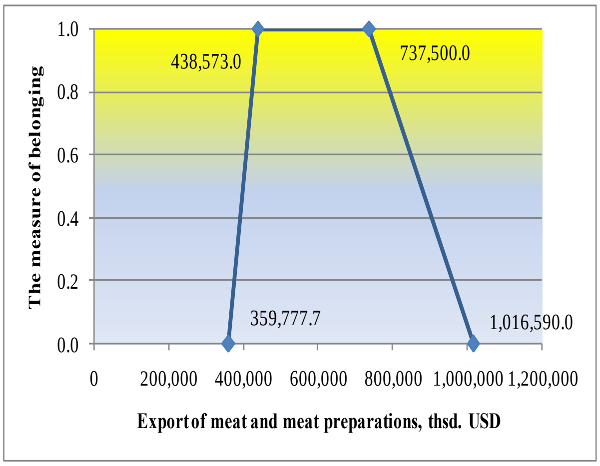


Fig. 3. Trapezoidal fuzzy interval for product 02 meat and meat preparations.
Source: Constructed by the author based on Tables 2 and 3.

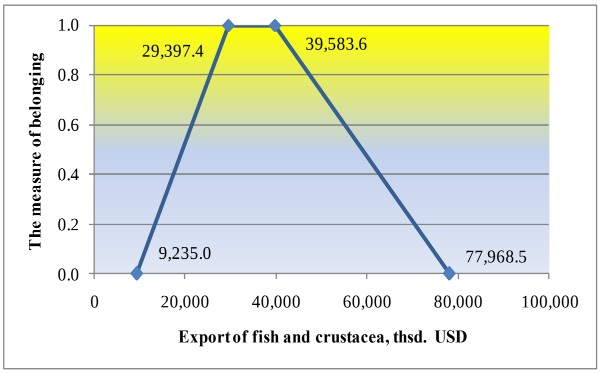


Fig. 4. Trapezoidal fuzzy interval for product 03 fish and crustacea.
Source: Constructed by the author based on Tables 2 and 3.

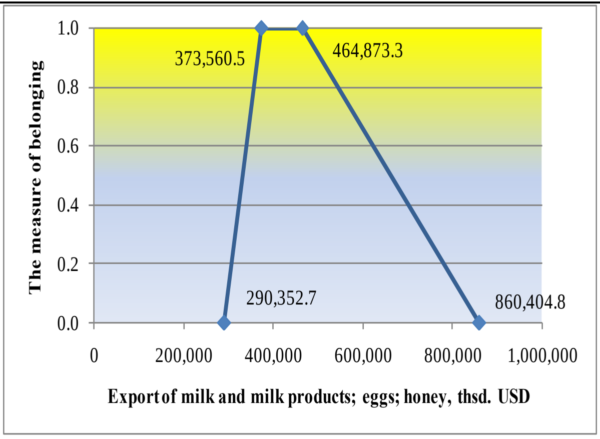


Fig. 5. Trapezoidal fuzzy interval for product 04 milk and milk products; eggs; honey.
Source: Constructed by the author based on Tables 2 and 3.

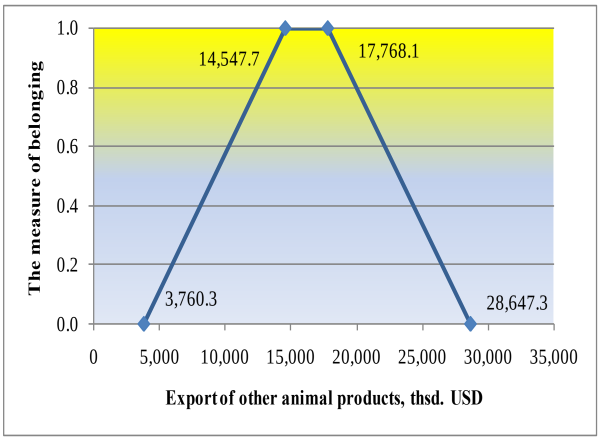


Fig. 6. Trapezoidal fuzzy interval for product 05 other animal products.
Source: Constructed by the author based on Tables 2 and 3.

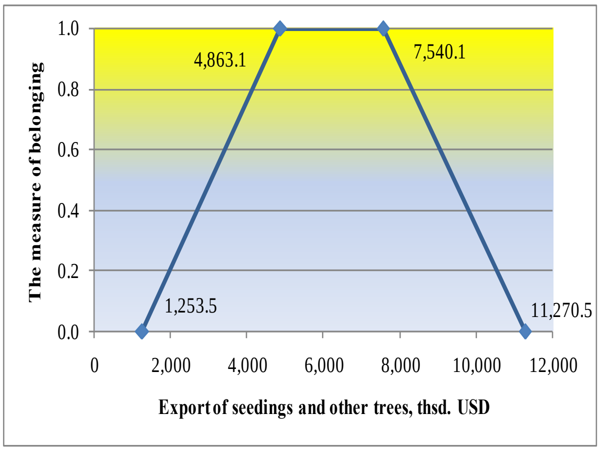


Fig. 7. Trapezoidal fuzzy interval for product 06 seedlings and other trees.
Source: Constructed by the author based on Tables 2 and 3.

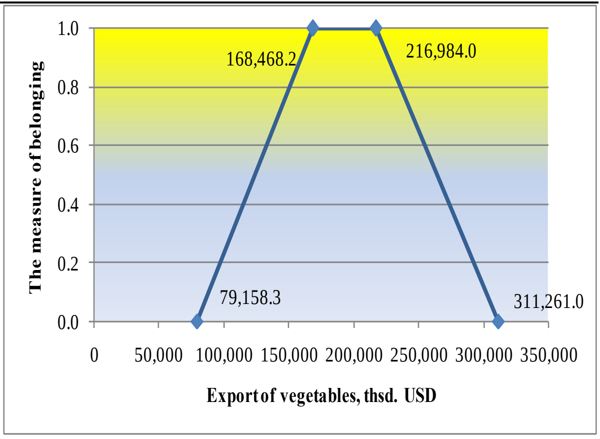


Fig. 8. Trapezoidal fuzzy interval for product 07 vegetables.
Source: Constructed by the author based on Tables 2 and 3.

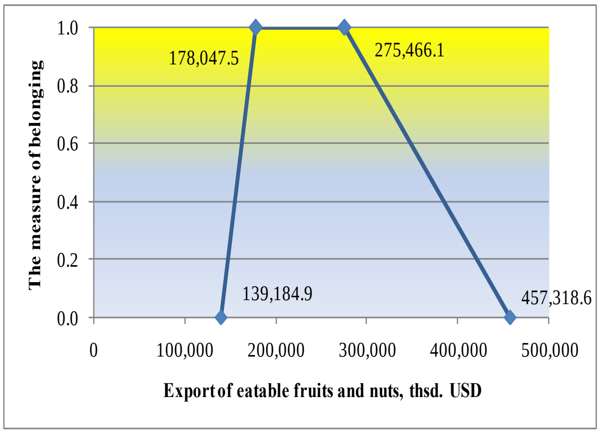


Fig. 9. Trapezoidal fuzzy interval for product 08 eatable fruits and nuts.
Source: Constructed by the author based on Tables 2 and 3.

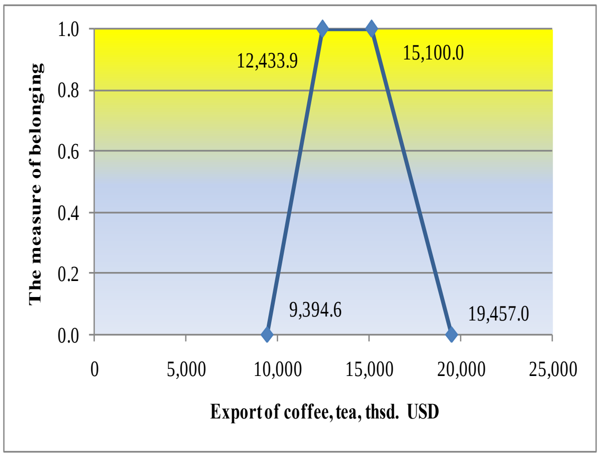


Fig. 10. Trapezoidal fuzzy interval for product 09 coffee, tea.
Source: Constructed by the author based on Tables 2 and 3.

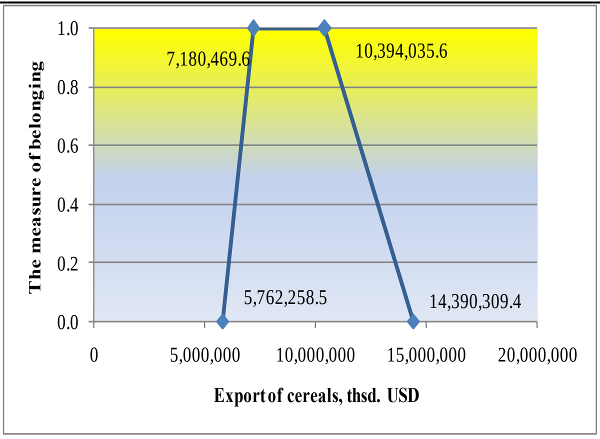


Fig. 11. Trapezoidal fuzzy interval for product 10 cereals.
Source: Constructed by the author based on Tables 2 and 3.

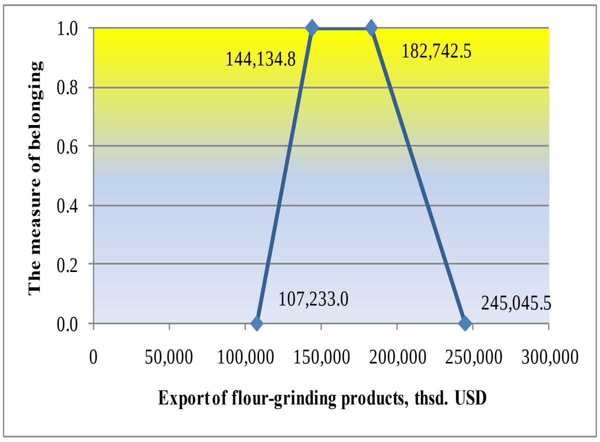


Fig. 12. Trapezoidal fuzzy interval for product 11 flour-grinding products.
Source: Constructed by the author based on Tables 2 and 3.

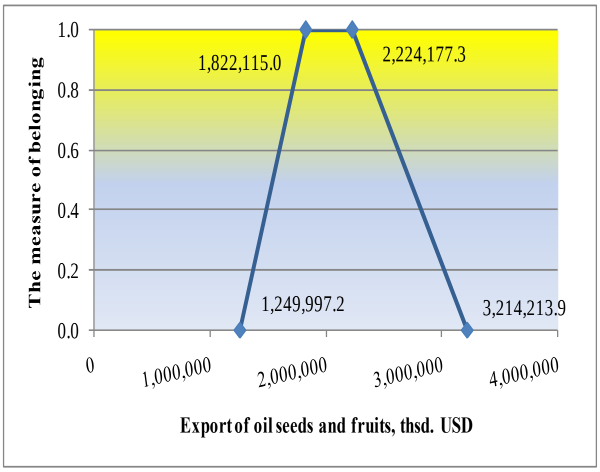


Fig. 13. Trapezoidal fuzzy interval for product 12 oil seeds and fruits.
Source: Constructed by the author based on Tables 2 and 3.

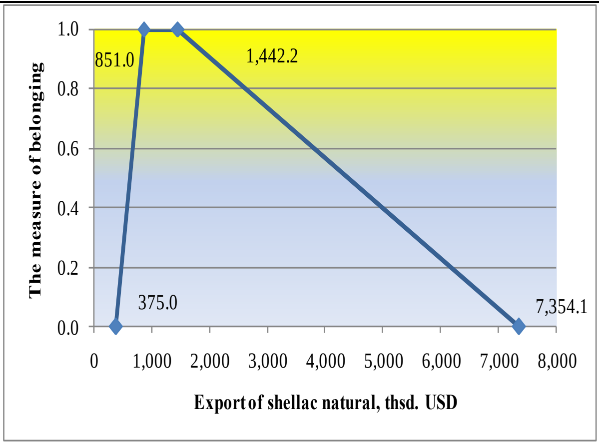


Fig. 14. Trapezoidal fuzzy interval for product 13 shellac natural.
Source: Constructed by the author based on Tables 2 and 3.

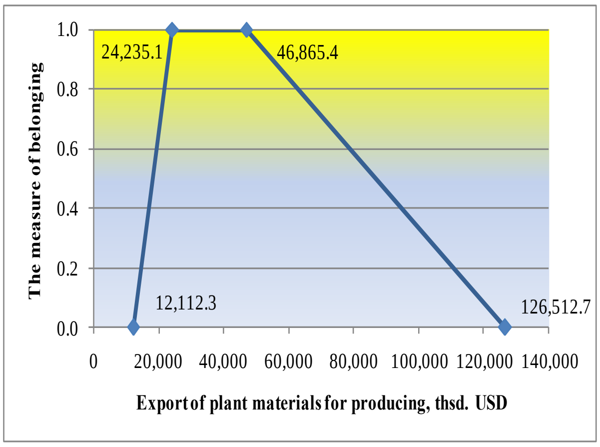


Fig.15. Trapezoidal fuzzy interval for product 14 plant materials for producing.
Source: Constructed by the author based on Tables 2 and 3.

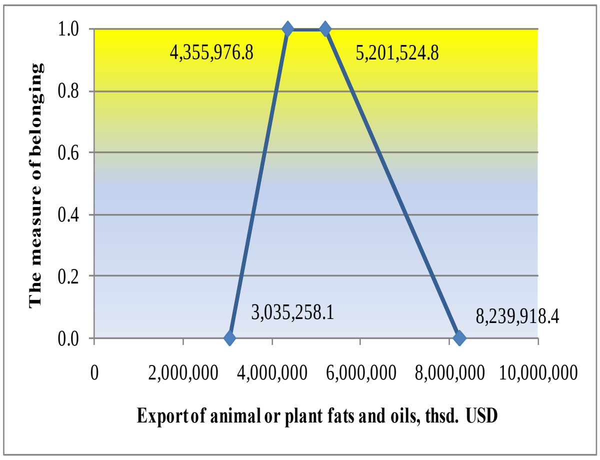


Fig. 16. Trapezoidal fuzzy interval for product 15 animal or plant fats and oils.
Source: Constructed by the author based on Tables 2 and 3.

In these figures, the upper base of the trapezoid is the optimistic interval; the sides of the trapezoid are the pessimistic interval. The forecast indicator has the highest probability of falling into the optimistic interval (measure of belonging). Deviation of the forecast indicator from this interval in a larger or smaller direction (pessimistic interval) has a lower probability of verification. It is unlikely that the forecast indicator will fall outside the pessimistic interval.

## CONCLUSIONS

In the context of the European integration of Ukraine and international trade on world agro-industrial markets, it is necessary to constantly monitor and forecast the indicators of the export of agricultural products. Analysis of actual data of the State Statistics Service of Ukraine for 2014–2021 regarding the commodity structure of foreign trade (exports) in agricultural products of Ukraine showed that the following types of goods had the greatest export potential (over 100 million USD annually): 02 meat and meat preparations; 04 milk and milk products; eggs; honey; 08 eatable fruits and nuts; 10 cereals; 11 flour-grinding products; 12 oil seeds and fruits; 15 animal or plant fats and oils. At the same time, the following types of goods had the lowest export potential (less than 10 million USD annually): 06 seedlings and other trees; 13 shellac natural. In the analyzed period, all types of goods (except 04 milk and milk products; eggs; honey; 14 plant materials for producing) had positive dynamics of most or half of the export indicators. For each of the 15 types of agricultural products, forecast indicators of the value of exports for 2022 in the form of trapezoidal fuzzy intervals were constructed according to the author's methodology. It will be possible to check whether the war in Ukraine will prevent the achievement of these indicators after the end of 2022.

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# QUALITY IMPROVEMENT FOR THE PRODUCT GINGERBREAD, CORELATIONS BETWEEN THE PRODUCT'S PHYSICAL AND CHEMICAL PROPERTIES AND THE RHEOLOGICAL CHARACTERISTICS OF DOUGHS

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***Abstract***

*Quality management reflects on the product gingerbread by applying the Customer Orientation and the Continuous Improvement principles, also by analysing and developing the product in terms of the influence exerted by the various quantities of ingredients and the use of dough maturation.The presented study made corelations between the physical and chemical parameters of the finished products and the rheological characteristics of doughs. Dough with varying wheat and rye flour ratios were made, being left to mature for 30 and respectively 150 minutes. Corelations were made between the specific volume of the product and the rheological characteristics of the doughs. The dough's consistency measured with the farinograph after 10 minutes of mixing and the widening percentage of the gingerbread in the baking process were corelated. The variation of the dough's volume during maturation was studied after 30 minutes of maturation, respectively 150 minutes of maturation. The results obtain inform with regard to the influence that the rye flour ratio has on the distortion of the product during baking, on the consistency of the dough and on the specific volume.*

***Key words***: *gingerbread, rheological characteristics of the dough, physical and chemical parameters, quality indicators*

## INTRODUCTION

An important component in quality improvement for gingerbread is the addition of rye flour in the dough. Compared to wheat, rye is milled and used in the form of higher extraction flours, which makes these products have a higher nutritional value and improved potential to obtain functional products [9, 12]. In gingerbread manufacturing, rye flour has high applicability. The fact that the colour of rye flour is darker than that of wheat flour, at the same extraction level, is not an impediment as long as the colour of the product is darker because of the added spices. The product's strong spices cover the marked taste of rye compared to wheat.

Wheat flour represents an important ingredient for the manufacture of gingerbread, as it has low gluten content, and the forming of gluten is inhibited by the high fibre content[11]. The gluten formed by the rye flour proteins is less resilient and more plastic [10]. The formed dough has low resilience and high plasticity, as well as increased stickiness [1]. Rye flour is a very good alternative to the "dilution" of wheat flour, more specifically for the "dilution of gluten" in the wheat flour [2].

Rye flours are highly varied, differing due to their composition [3] and, therefore, due to their technological properties. As in the case of wheat flour, extraction is used to classify such flours. Medium-extraction flours are preferred because, as the extraction is higher, the proportion of the fraction made up of bran also increases, a fraction that has a stronger taste and is more bitter [8]. For this reason, semi white rye flours are preferred in the manufacture of gingerbread. According to the studies conducted by Fustier et al., insoluble wheat fibres (the tailings obtained in the centrifugal separation of starch) [5], [6], [7] have a higher impact on the product characteristics than gluten, they cause higher density and firmness of products, and they have a negative effect on the symmetry of the products. If we extend this observation to rye flour fibres, as well, it appears that low extraction rye flour is better suited for the manufacture of gingerbread, due to the lower content of hemicelluloses.

The replacement of wheat flour with rye flour leads to products having sensorial characteristics superior to the situation where the wheat flour is replaced with flours from other cereals, such as buckwheat [4].

This study aimed to identify certain corelations between the physical and chemical parameters of the finished products and the rheological characteristics of doughs.

## MATERIALS AND METHODS

To obtain the gingerbread samples, wheat flour type 650 was used, having an ash content of 0.640%, 14.6% moisture, 24.6% wet gluten, and rye flour with a content of 0.950 mineral substances, moisture 13.9%. The invert sugar syrup had 64% dry matter, and the caramel 80%. Wheat flour was replaced with rye flour (in percentages ranging from 10 to 50%), and the dough obtained was left to mature for 30 and 150 minutes.

Table 1. Standard manufacturing recipe

| No | Raw matter | Quantity, kg |
|---|---|---|
| 1 | Wheat flour | 4.84 |
| 2 | Rye flour | 0.24 |
| 3 | Starch | 0.29 |
| 4 | Sodium bicarbonate | 0.071 |
| 5 | Ammonium bicarbonate | 0.035 |
| 6 | SAPP 28 (sodium acid pyrophosphate) | 0.035 |
| 7 | Clove | 0.019 |
| 8 | Cinnamon | 0.077 |
| 9 | Salt | 0.017 |
| 10 | Lecithin | 0.036 |
| 11 | Hydrogenated fats | 0.36 |
| 12 | Sorbitol | 0.29 |
| 13 | Glycerine | 0.048 |
| 14 | Honey | 0.19 |
| 15 | Invert syrup | 2.86 |
| 16 | Caramel | 0.58 |
| | **TOTAL** | **10** |

Source: Original.

For the study of dough behaviour upon kneading, the AACC 54-21 Farinograph Method for Flour (AACC 1995) was used, the method of the dough's constant mass.

This option was selected because the gingerbread dough is very complex, it contains a large number of ingredients which are added to a greater extent than in the bread manufacture doughs. Consequently, in order to minimize the influence of the kneaded dough mass on dough consistency, this method was preferred, where the dough mass is always of 480 grams.

To prepare the doughs, the reference recipe from Table 1 was used.

## RESULTS AND DISCUSSIONS

The maximum consistency of the doughs made with various rye flour proportions was analysed in comparison with the widening, the H/D ration, and the products' specific volume. All trend curves had regression coefficient values of less than 0.4000, which indicates that no correlations can be established between dough consistency and the physical-chemical characteristics of the products. This is somewhat expected, as the considered consistency was not the maximum value, but rather the consistency after 60 minutes of mixing, as the maximum consistency could not be attained according to the farinograph in the 60 mixing minutes, and the dough's consistency increased too much, threatening the proper operation of the instrument.

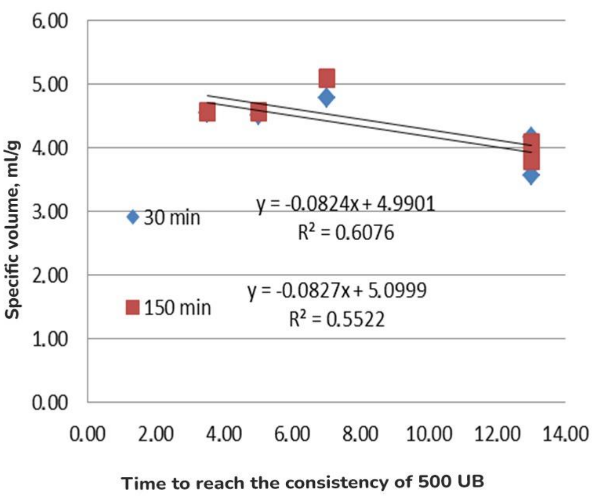


Fig. 1. Corelations between the specific volume and the rheological characteristics of doughs with various rye flour proportions

Source: Own results in the laboratory.

Much better characteristics were obtained when the physical and chemical characteristics of gingerbread were placed in relation with the time needed to reach the consistency of 500 UB. When analysing the specific volume of the samples, linear regression factors of 0.76 and 0.78 were noticed (Figure 1). These two values, even though they seem low, are considered to be significant for the experimental rheology tests.

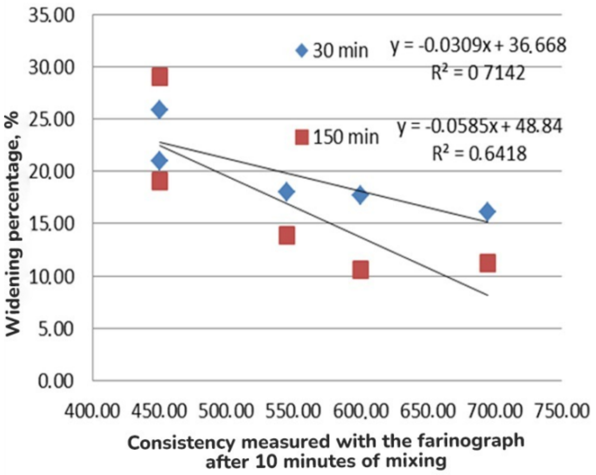


Fig. 2. Corelations between the consistency measured with the farinograph after 10 minutes of mixing and the widening percentage of the gingerbread during baking
Source: Own results in the laboratory.

Another parameter considered for the characterization of the farinograph curves specific for the mixing of gingerbread doughs was the consistency of the dough after 10 minutes of mixing. Significant values for the linear regression factors were only noted when the widening of the dough pieces in the baking process was considered. We can note in Figure 2 that these regression factors had values of 0.7142 and respectively 0.6418 for matured doughs, for 30 and respectively 150 minutes. These values confirm that, to widen gingerbreads, the consistency of the dough is important. When increasing the farinograph mixing time, the values of the linear regression factors became increasingly lower.

**The variation of dough volume during maturation**

During the maturation process, decomposition of the chemical aerating agents occurs as a result of the reaction between the sodium and ammonium bicarbonate and the acidifiers employed. Gas evolution led to high porosity of the dough, which made it less dense and easier to handle. The rate of decomposition of the gases depends on temperature and on the type of acidifiers employed. The higher the temperature of the dough, the higher the quantity of formed gas, as the speed of reaction is higher at high temperatures. The temperature of the dough also conditions the solubilisation rate of acidifiers. In recipes for manufacturing, various acidifiers may be employed, depending on the time when the gas release is intended, whether during kneading, during fermenting, in the first part of the baking or towards the end of the baking cycle.

As a result of gas evolution during maturation, an increase in volume occurred, as these gases were retained in the dough. The increase in volume was not proportional to the quantity of released gas, just as the quantity of released gas was not proportional to the quantity of aerating agents that reacted. Such disproportionalities are due to the physical properties of the doughs. As a result of the chemical reaction of aeration agent decomposition, $CO_2$ and $NH_3$ are released at a constant rate. These substances are released in a constant manner but, in a first stage, they are dissolved in the liquid stage of the dough. When the saturation concentration is reached, the substances will reach the gaseous stage and will start to accumulate, leading to an increase in volume. Several types of pressure act on the gas present in the dough, leading to gas compression. The more cohesive the dough, the higher the pressure exerted on the gas and, as a result, the volume growth will be lower. Strong flours make strong doughs, which do not allow for volume growth.

In the study performed, the only variable was the proportion between rye flour and wheat flour, which means that the evolution rate of gas is identical in all these. If differences occurred in terms of gas evolution, they were due to the various retention capacity of gases, as well as to the pressure exerted on them.

Figure 3 presents the dynamics of dough volume changes during maturation for the doughs made with varying rye flour proportions, after 30 minutes of maturation.

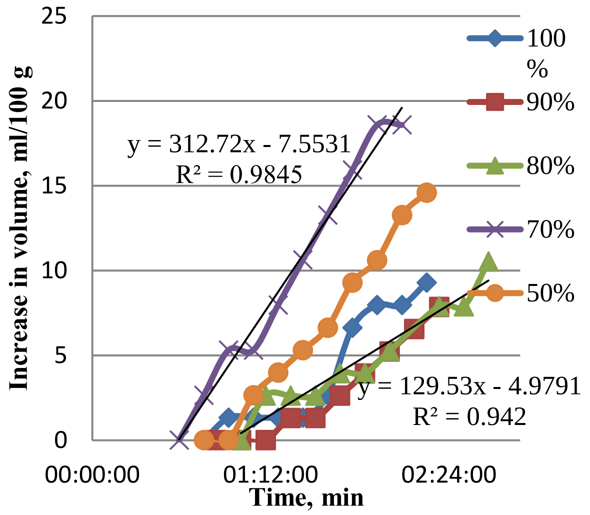


Fig. 3. Variation of the dough's volume during maturation after 30 minutes of maturation
Source: Own results in the laboratory.

The figure indicates that the development of doughs with a higher rye flour proportion was more effortless, their volume increased faster. As the production of gas was similar due to the identical quantity of aeration agents and to the identical working conditions, the differences may only be ascribed to the fact that doughs with more rye flour have better extensibility. Due to the lower pressure, the gases diluted more.

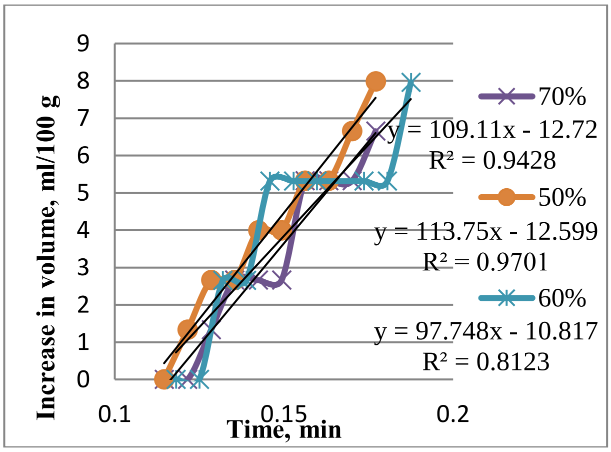


Fig. 4. Variation in the dough's volume during maturation after 150 minutes of maturation
Source: Own results in the laboratory.

After 150 minutes of maturation, the differences between the curves were lower (Figure 4). Also, the trend line slope was reduced, indicating a lower gas formation rate. As SAPP 28 was used for aeration, it may be that the part having low granulation and fast dissolution had already reacted, and only the coarser and lower-dissolving component reacted with the bicarbonates and released gases.

## CONCLUSIONS

The higher the rye flour ratio in the dough, the lower the widening of the products during baking. The differences between the samples having various rye flour ratios were lower for the 30-minute maturation time.

The higher the rye flour ratio, the greater the dough consistency, which led to lower widening of the dough pieces. The weight of the dough piece also played a lesser role in terms of widening, as the latter depended to a much higher extent on the rheological changes of the dough.

Also, when weighting the widening of the cookies with their initial mass, the best correlation was noticed in the case of doughs matured over a longer period of time.

During baking, the doughs with a higher wheat flour ratio were more fluid, with a higher widening tendency.

Maturation time had no effect on the products' specific volume. The specific volume depended on the rye flour ratio within the mixture. However, there are other factors which influence the samples' specific volume, as linear regression factors were not very high. During maturation, certain processes take place, which influence the specific volume, as the linear regression factor for the trend curve corresponding to the samples having a 150-minute maturation time is low, namely 0.558.

The doughs with a greater rye flour ratio had better extensibility.

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# QUALITY IMPROVEMENT FOR THE PRODUCT GINGERBREAD, A STUDY REGARDING THE INFLUENCE OF RYE FLOUR ON THE PRODUCT'S TEXTURAL CHARACTERISTICS

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***Abstract***

*In view of obtaining high-grade and competitive products, food industry manufacturers, as well as others, place the client, the consumer, at the top of the quality pyramid. The application of the Customer Orientation principle is essential. For the product "gingerbread", the subject of this work, textural analysis is used as a survey method, to improve the quality of the product. Gingerbread manufacturers, aiming to satisfy the clients' requirements, study the behaviour of the products developed by using various ingredients, in different proportions, with various maturation times and with water activities originating from different moisture levels of the product. Such values are intended to particularize the product and to assign it better quality and preservability during the validity term. Thus, in this survey, wheat flour was replaced with rye flour in different percentages, and the dough obtained was left to mature for 30, and respectively 150 minutes. The textural properties of the finished product were analysed, having an impact on the consumer, namely hardness, strength, and resilience. These parameters subject to analysis can be considered quality indicators for gingerbread. It was determined that the replacement of wheat flour with rye flour to a certain percentage leads to minimum toughness of the product. Corelations were made with maturation times, as well as with the moisture of the product. Maturation processes are complex, and the effects of the various factors considered are contradictory.*

***Key words*: *gingerbread, rye flour, textural characteristics, quality indicators.***

## INTRODUCTION

Gingerbread is a product that is difficult to obtain as part of industrial continuous flow processes, because of the characteristics of sticky doughs and of the technology used to obtain the dough pieces. Wire cutting is used for simple gingerbread, and coextrusion for gingerbread having various filling proportions. The compromise occurs because of the doughs' ability to be processed when they are formed.

Instead, it is important to analyse the hardness of the product, its strength and resilience, parameters representing textural quality indicators for the finished product [11].

The presence of rye flour in the doughs is responsible for this sticky consistency, the doughs are less cohesive, but they have positive effects on the textural characteristics of the finished products, which become softer, they attain a superior, more tender texture [2], [3], [9]. This aspect is due to the lower quantities of gluten proteins in the dough with added rye flour and also to the limited development of gluten during kneading, because of the pentosans present in large quantities [1], [5], [4].

An in-depth study on the sensory perception of texture was conducted by Foegeding et al [6]. The assessment of product quality involves more than an analysis of appearance, smell, and taste [8]. Rye flour has an influence on tthe quality of the final product and also on its physical and chemical properties [1].

In view of elaborating the most accurate tests possible, which are closest to the consumer's perception, it is necessary to explain the sensorial perception and the discovery of the mechanical aspects of sensorial analysis, to identify the parallels with the instrumental textural evaluation [7], [10].

This study monitored the effect which the replacement of wheat flour with rye flour has on the products' textural characteristics. Wheat flour was replaced in the basic recipe, which contained 100% wheat flour, with rye flour percentages ranging from 0 to 50%. The dough was matured for 30 and 150 minutes.

## MATERIALS AND METHODS

Ordinary raw materials were used to obtain the product: white wheat flour, rye flour, sodium bicarbonate, ammonium bicarbonate, sodium acid pyrophosphate (SAPP), cloves, cinnamon, salt, lecithin, sorbitol, glycerine, honey, invert sugar syrup, and caramel. The product was derived industrially.

To prepare the dough, white wheat flour type 650 was used. Rye flour had a mineral content of 0.950 % and a moisture content of 13.9%. The inverted sugar syrup and the caramel syrup were industrially manufactured (64% dry matter and respectively 80% dry matter).

For texture tests, the TexVol TVT-300XP/XPH texture meter manufactured by the company Perten Instruments, Sweden, was used. The instrument was equipped with a 15 kg load cell. The test device employed was the blade version, a device imitating the bite, the shearing of the product between the incisors (Figure 1).

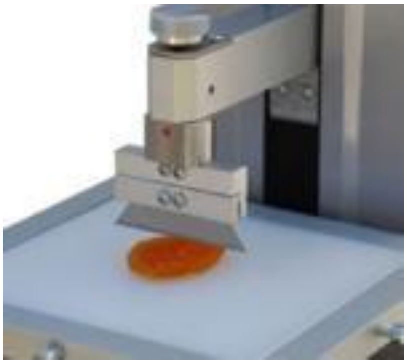


Photo 1. Blade device used for testing
Source: Original from laboratory.

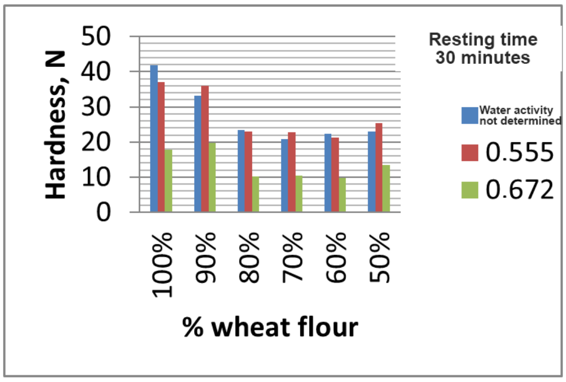
## RESULTS AND DISCUSSIONS

Gingerbread, after a 60-day preservation, was analysed in terms of texture, by cutting with the texture meter's blade device. Given that product dehydration occurred during storage, it was resorted to rehydration by placing it in a controlled relative humidity environment. Two water activities were provided, 0.555 and 0.672. The products stored in the warehouse were also analysed, and their water activity was not determined.

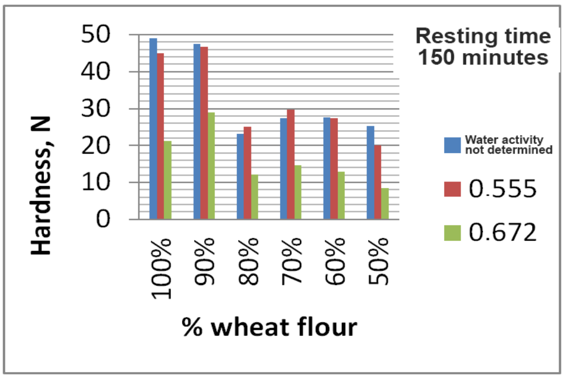
Figure 1 provides a graphic presentation of the values obtained for gingerbread hardness. Maximum hardness and force represent the same characteristic, namely the force needed to advance the device, in this particular case a blade, into the product. The hardness was recorded when the device penetrated the sample for the established distance

As the device was still advancing into the product, the recording was continued for compression tests, as well, with the maximum force occurring in this portion. For this reason, the maximum force was also analysed.

The gingerbread prepared with different resting times were tested, 30 and respectively 150 minutes of rest.




*a. Hardness by % wheat flour at 30 minutes by % of wheat flour*




*b. Hardness by % wheat flour at 150 minutes by % of wheat flour*

Fig. 1. Hardness of the gingerbread made with various rye flour proportions, at different dough resting times and different water activities (N)
Source: Own results in the laboratory.

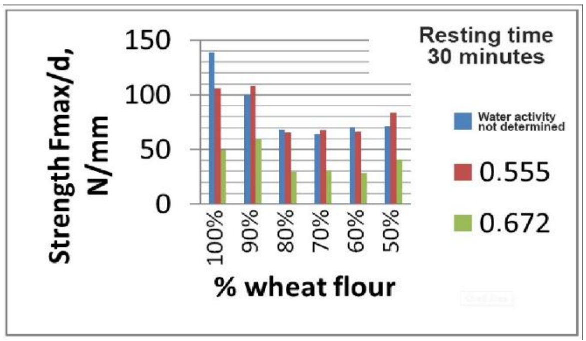
Figure 1 indicates that the added rye flour radically influenced the textural characteristics of the gingerbread. The higher the rye flour proportion, the more significant the reduction in hardness, in the resistance upon insertion of texture meter's cutting knife. The lower hardness was visible starting from the recipe where wheat flour was replaced with rye flour to a 20% rate. A replacement rate of only 10% led to slight increases in hardness. The most visible decrease was noted for the 20% replacement ratio. Upon increasing the rye flour ratio above 20%, the changes are quite low.

The figure also indicates that maturation time influenced the characteristics of the products. Surprisingly, with large proportions of wheat flour, resting time led to significant increase in product hardness. If we refer to the hardness of the product without conditioning (without humidification), using the same rye flour proportion, we noted, in almost all case, increases in hardness in proportion to the increase in resting time. A pattern for such growths could not be noticed, which proves that the transformations that occurred in the dough during maturation were complex and it is very likely that some of them had contradictory effects.

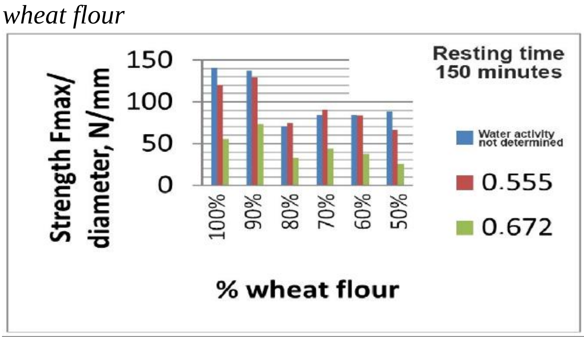
The situation is difficult to analyse without also considering the effect of humidification. The previous experiments led to the finding that hygroscopicity highly influenced the behaviour of gingerbread during storage. For this reason, humidification was employed for gingerbread, enabling its comparison by taking into account all the factors that may influence the process. The data obtained confirmed the fact that gingerbread moisture influences the textural characteristics of products to a great extent. The differences between the conditioned gingerbread and the gingerbread unconditioned up to a water activity level of 0.555 were not significant. Subsequent laboratory assessments confirmed that water activity for these samples was very close to that of the conditioned samples (between 0.480 and 0.560). Much greater differences were noticed when the conditioning was achieved up to a water activity level of 0.670.

With the increase in resting time, sample hardness increased for almost all samples. A significant exception was noted for the gingerbread where 50% of the flour was replaced with rye flour, its hardness decreasing by 21, respectively 37%, compared to the hardness of the gingerbread where only the resting time varied.

Where the hardness of conditioned gingerbread was analysed up to a water activity level of 0.555 and 0.670, prepared with a 30-minute resting time, it was noticed that for a water activity of 0.555 hardness decreased, as compared to the 100% wheat flour sample, insignificantly for gingerbread with 10% rye flour, but with values between 31.5 and 42.3% for gingerbread in which the rye flour proportion increased from 20 to 50%. If the same reference is maintained in the case of a water activity increase up to 0.670, hardness decreased even more, with values contained between 46.5 and 73.8%. In principle, a decrease in hardness by almost half was noticed in the case of samples which were moistened to a higher rate (Figure 2).




*a. Strength by % wheat flour at 30 minutes by % of wheat flour*



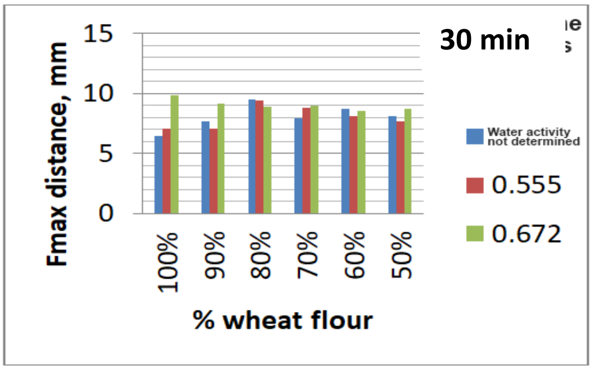

*b. Strength by % wheat flour at 150 minutes by % of wheat flour*

Fig. 2. Strength of the gingerbread made with various rye flour proportions, at different dough resting times and different water activities (N/mm)
Source: Own results in the laboratory.

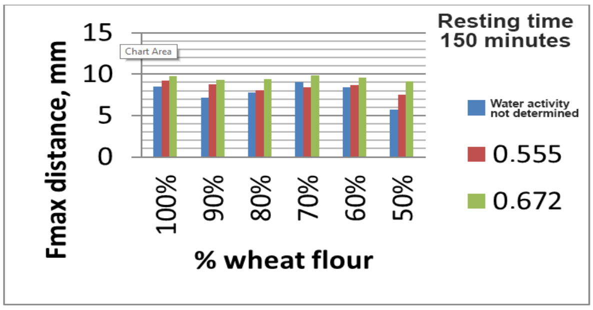
Similar behaviour was also noticed in the case of gingerbread prepared with 150 minutes of rest.

The graphs in Figure 2 were analysed, obtained for gingerbread strength, in parallel with the ones for hardness, and no major differences were noted, which led to the conclusion that the samples were relatively homogenous.

The distance where maximum force was recorded is another important parameter for the textural characterization of the samples. Figure 3 provides the average values for this parameter.




*a. Distance by % wheat flour at 30 minutes by % of wheat flour*




*b. Distance by % wheat flour at 150 minutes by % of wheat flour*

Figure 3. Distance for $F_{max.}$ in the case of the gingerbread made with various rye flour proportions, at different dough resting times and different water activities (mm)

Source: Own results in the laboratory.

It can be noticed that, with the increase in water activity, for samples with 30-minute rest and for the ones with 150-minute rest, a growth in cutting depth occurs, for which maximum force is registered. To understand this parameter, we have to specify and emphasize the fact that the gingerbread was not sectioned in whole, but rather only for a 10 mm depth. As the knife advanced into the gingerbread, it could cut directly if the tested sample was not compressible or, if it was compressible, then the sample was compressed before cutting, and the compression of the layers led to higher hardness. If the maximum force was reached at a smaller penetration distance, this indicates that the product was crumblier. Upon reaching maximum force, the product is mechanically destroyed along the knife advancement line, which renders lower the resistance after reaching this point.

When we interpret this parameter in view of this reasoning, we can say that the products having lower rye flour content were crumblier and that, with the increase in water activity, product brittleness decreased.

This observation was also confirmed by the aspect of the curves recorded by the texture meter and presented in Figure 4.

It was noticed that, for small water activities, the curves start suddenly, reaching a maximum, and then the registered values decreased until the maximum cutting depth was attained.

The lower the water activity, the more cohesive and compressible the product, which makes the maximum force to increase gradually and to reach the maximum cutting depth.

For products with 50% rye flour, this finding is even more obvious. Upon increasing resting time, an inversion was noted.

Products with rye flour were crumblier than the ones where only wheat flour was used.

Resilience is associated in terms of texture with the ratio between the areas below the texturometric curve upon advancement of the testing device and those upon withdrawing the testing device, respectively.

The analysis of Figure 4 capitalizes and clarify the notes based on the interpretation of the maximum distance variation mode and in the texturometric curves. Resilience is first of all influenced by resting times, as well as by water activity. The analysis of these figures indicates that it is not a possible resilience of samples that determines the increase in the distance for attaining maximum force.

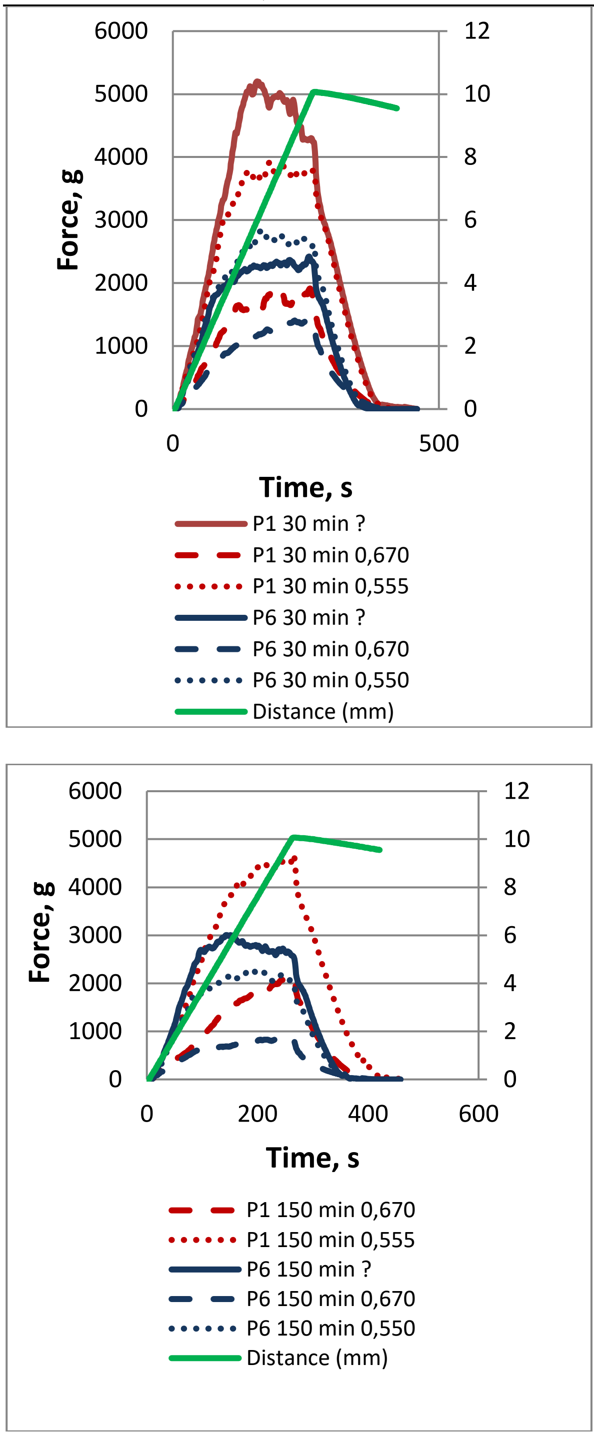



Fig. 4. Texturometric curves for the gingerbread made with 100% and 50% rye flour, at 30 and 150 resting minutes for the dough.
Source: Own results in the laboratory.

This parameter is influenced by product brittleness. It can be noticed that the curves with high distance for attaining the maximum force have a more regular aspect, whereas the other ones are more irregular, due to small fractures occurring in the product.
The resilience of products with smaller rye flour proportion is greater for lower dough resting times and for low water activity. As water activity increases, resilience decreases. Gingerbread with 50% rye flour and more moisture were more resilient than the dry ones. The increase in resting time led to lower resilience values, particularly for those conditioned at higher moisture (Figure 5).

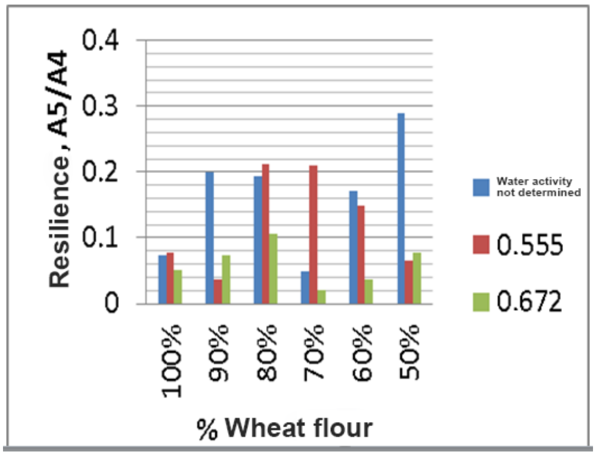



Fig. 5. Resilience of the gingerbread made with various rye flour proportions, at different dough resting times and different water activities.
Source: Own results in the laboratory.

## CONCLUSIONS

Products with a lower rye flour content are crumblier and, as water activity increases, product brittleness decreases.
Surprisingly, with large proportions of wheat flour, resting time led to significant increase in product hardness.
If we refer to the hardness of the product without conditioning (without humidification), using the same rye flour proportion, we noted, in almost all case, increases in hardness in proportion to the increase in resting time.
A pattern for such growths could not be noticed, which proves that the transformations occurring in the dough during maturation are complex and it is very likely that some have contradictory effects.

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# EFFECTS OF INFORMATION COMMUNICATION AND TECHNOLOGY (ICT) USAGE ON POULTRY FARMERS IN JALINGO LOCAL GOVERNMENT AREA OF TARABA STATE, NIGERIA

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***Abstract***

*The study assessed the effects of information and Communication Technology usage among poultry farmers in Jalingo local government area of Taraba State, Nigeria. The data was collected using well-structured questionnaires and inferential and descriptive statistics were used to analyze the data. Multi-stage random and purposive sampling techniques were used to select ninety (90) respondents using for the study. Socio-economic characteristics of the respondents showed that 84.4% were male and 15.5% were female and 40.5% of them were within their productive age while 53.6% were married and majority was literate. The study also revealed that the most accessible and used ICT facilities in the area included: radio, mobile phones and television. The access and use of ICTs in the study area was also high. Some of the constraints associated with usage of ICT facilities were identified in the study include high cost, inconveniences, lack of availability and reliability. The major sources of information for farmers in the study area were telephone calls, radios, televisions, words of mouth, text messages and training. The main factors affecting the use of ICT facilities by poultry farmers in the study area were Sex, age, educational status and source of income. Based on these findings, the study recommended that relevant policies aimed at improving agricultural productivity should ensure farmers have adequate access to ICT facilities. Extension workers should also help to improve farmer's knowledge and skills of ICT facilities to enhance adoption of ICT facilities by farmers and thus improve productivity.*

***Key words***: *Information Communication Technology, poultry farmers*

## INTRODUCTION

Many human civilizations have modified their social structures over thousands of years to reflect the requirement for agricultural productivity. A growth in population with an adaptation to farming practices that lead to increased crop yields. However, the globe is currently confronted with rising populations, restricted crop yields, and significant amounts of waste generated by both the food supply chain and consumers in Western economies. In regard to the increase in the world population, the need for increase in production will be achievable if information, communication and technology (ICT) are put in place. An expanding ICT sector can help to boost overall productivity, GDP, and trade. As individuals continue to embrace ICT in order to improve their lives, it may have an impact on how they live and how quickly they develop [6]. In conjunction with megatrends which include globalization, weather change, urbanization, and getting old populations, the effect of generation on our each day lives and monetary interactions is undeniable; ICT is assisting to convert our society and the monetary systems which have fashioned the muse of industries because the business revolution. The globe is shifting from a period of abundant food to one of shortage [2].

The internet is used by more than 40% of the world's population. There are considerable initiatives underway to link those sectors that are still disconnected, mostly in developing countries' rural areas. The rapid transition from mobile phones to broadband has facilitated the rapid creation of a slew of new information and communication channels, including social media, portable cloud computing, big data, and smart terminals, all of which are unquestionably influencing human life. Mobile phone subscriptions are affecting not only people's lives but also how data and information is collected, saved, analyzed, and shared, as well as providing new ways to do business online and offline in terms of buying, selling, marketing, and financial transactions [5].

Information and communication technologies (ICTs) have long had an impact on agriculture, and many forms of indigenous knowledge continue to play an important role in agricultural management [12]. However, in the developing world, the mobile phone is a ubiquitous technology of urban-rural socio-economic speed, and it is seen as a development tool for "leaping froging" legacy infrastructure and innovating faster than through traditional industrial forms. Farmers' access to, interchange of, and manipulation of information is being accelerated by mobile phones, which is reshaping the way farmers engage with markets and cities. Farmers are increasingly using social and commercial networks to focus, search, and extract important and up-to-date market information [4, 7]. The internet, cell phones, radio, and television are the most essential communication instruments for farmers seeking agricultural expertise and information. Positive results in agricultural development have been attained by implementing these technologies in many countries [3].

**Statement of the Problem**

The globe is transitioning from a period of abundant food to a period of shortage. The world's grain reserves have shrunk by a third in the last decade. Food prices have more than doubled globally, sparking a global land rush and ushering in new food geopolitics. Food is believed to be the new oil, and land is considered to be the new gold [2]. The dissemination of better technologies to farmers is a crucial task in agricultural growth. It is critical that ICTs be used to gather information regarding poultry farming in Nigeria.

For Nigeria, poultry farming is a very important sector of agriculture where profitable small business is developed either in broilers and layers rearing [1, 8, 11].

One of the strategies to enhance poultry production in Nigeria, according to [7], is to provide the relevant information through acceptable channels that are accessible to the farmers for whom the information is intended. The poultry industry in Nigeria can benefit from the availability of ICTs to increase chicken output. To do so, it'll be necessary to figure out how many poultry farmers have access to and use ICTs for development [9, 10].

**Objectives of the Study**

The study was designed to determine the effects of ICT on poultry farmers in Taraba state. Specifically, the objectives were to describe the socioeconomic characteristics of the respondents in the study area, identify ICT facilities in the study area, examine the effects of ICT usage on poultry farmers in the study area, describe the constraints associated with ICT usage among poultry farmers determine the as well as factors influencing the usage of ICT among farmers in the study area.

## MATERIALS AND METHODS

The investigation was conducted in Jalingo Local Government area of Taraba state, Nigeria. The state comprises of sixteen local government areas and geographically consists of undulating landscape dotted with few mountains features. Jalingo is arguably the most successful local government area in the State; it is also the most populated with a high range of development when compared to other states. About 25 miles southeast of the Benue River, Jalingo is located in the savanna-covered slopes of the Shebshi Mountain. It is a market town with a government dairy farm and is linked to Yola and Wukari via road. It has population inhabitants of 660,213 and a population density of 3,456.6/km$^2$ (8,952.6/sq mi). Geographically it is located between latitude 8.9, and longitude 11.3667, $8^0$ 54'0" North, $11^0$22'0" East. It holds the prime position of being the headquarter of the Muri Emirate Council and capital city of Taraba State.

**Sampling Procedures**

Purposive sampling and multi-stage random sampling technique was used to select respondents in the study area. Six (6) wards were selected from the 10 wards in the first stage. The six wards selected are Kona, Mayo Goi, Sintali, Turaki A, Turaki B and Barade. In the second stage, 3 farming communities and 15 famers were selected giving a sample size of 90.

**Method of Data Collection**

The study data were mainly from primary data with the use of well-structured pre-tested questionnaires administered to the farmers

**Method of Data Analysis**

Objective 1, 2, 3 and 4 were analyzed using descriptive statistics such as frequencies, Likert scale while objective 5 was analyzed using binary logistic regression. Objective 3 and 4 were analyzed using a 5 point Likert scale which was be scored as; Very high = 5; High = 4; Fairly High = 3; fair = 2; and Low = 1.

The mean score was then used as the endogenous variable in the regression model. Objective 5 was analyzed using regression technique. The model was specified as follows:

$$Yi=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\mu$$

where:

Y=Usage of ICT

$X_1$= sex of the respondent (Dummy: 1=male, 0=female)

$X_2$= Age in years

$X_3$= Occupation

$X_4$= Farming experience in years

$X_5$= Years of schooling

$X_6$ = Source of income

## RESULTS AND DISCUSSIONS

**Socio-economic Characteristics of the Respondents**

The socio-economic characteristics of the respondents revealed that 40.5% of the respondents fell within the age bracket of 21-30 years and age bracket of 31-40 years accounted for 33.3% while 97.6% of the respondents had formal education and 2.4% of them having only informal education. The results also showed that farming experience (1- 5 years) constituted about 48.8% while those with 6-10 years of farming experience accounted for about 40.5% of the respondents. The major (44.0%) source of livelihood discovered in the study area was farming and followed by civil servant (22.6%), artisan (22.6%) and trading (10.7%).

Table 1. Distribution of Respondents by Socio-economic Characteristics

| | Frequency | % |
|---|---|---|
| **Age** | | |
| 21-30 | 34 | 40.5 |
| 31-40 | 28 | 33.3 |
| 41-50 | 19 | 22.6 |
| >50 | 3 | 3.6 |
| Total | 84 | 100.0 |
| **Educational Qualification** | | |
| Secondary | 9 | 10.7 |
| High institution | 73 | 86.9 |
| Informal education | 2 | 2.4 |
| Total | 84 | 100.0 |
| **Farming experience** | | |
| 1-5 | 41 | 48.8 |
| 6-10 | 34 | 40.5 |
| 11-15 | 8 | 9.5 |
| >15 | 1 | 1.2 |
| Total | 84 | 100 |
| **Source of income** | | |
| Farming | 37 | 44.0 |
| Trading | 9 | 10.7 |
| Civil servant | 19 | 22.6 |
| Artisan | 19 | 22.6 |
| Total | 84 | 100.0 |
| **ICT Facilities** | | |
| Radio | 57 | 67.9 |
| DVD | 13 | 15.5 |
| Computer | 9 | 10.7 |
| Phone | 84 | 100.0 |
| Television | 68 | 81.0 |
| Internet | 63 | 75.0 |
| Flash drives | 16 | 19.0 |
| CDROM | 5 | 6.0 |

Source: Field Survey, 2022

67.9% of the respondent made use of radios to access relevant information while only 10.7% of the respondent made use of computers. This could however be as a result of the inaccessibility of usage of computers when compared to other Information Communication Technology facilities as well as its relative complexity of use. All (100%) the respondents selected used of mobile phones in sending and receiving messages and making calls to their customers while 81.0% of the respondent in the study area made use of television in getting and listening to relevant information, 75% of the respondents made use of internet, 19.0% of the respondent make use of flash drives in saving their files and other documents while only 6.0% made use of the CDROM. This might be as a result of the fact that CDROMs are outdated and are not widely used currently.

**Usage of ICT Facilities**

The data on Table 2 revealed that tablets extent of use has a mean score of 2.26 which implies that it was not widely used among the poultry farmers.

This might be as a result of the fact that tablets are expensive and not affordable in the study area. Also the study revealed that GSMs and Audio visual equipment had mean scores of 4.52 and 4.26 respectively which imply that they were widely used by poultry farmers in the study area because the fact that they are relatively easy and cheap to use.

Table 2. Extent of use of ICT Facilities

| Facilities | Very High (5) | High (4) | Moderate (3) | Low (2) | Very Low (1) | Total population | Mean score | Percentage % |
|---|---|---|---|---|---|---|---|---|
| Tablet | 1 | 1 | 26 | 38 | 11 | 77 | 2.26 | 91.7 |
| Laptop | 2 | 6 | 29 | 27 | 15 | 79 | 2.41 | 94.0 |
| GSM | 48 | 31 | 3 | 1 | - | 83 | 4.52 | 98.8 |
| Audio visual equipment | 30 | 45 | 4 | 1 | 1 | 81 | 4.26 | 96.1 |
| Calculator | - | - | 8 | 17 | 55 | 80 | 1.41 | 95.2 |

Source: Field Survey, 2022.

**ICT Facilities Used by Poultry Farmers in the Study Area**

Table 3 shows ICT facilities used for the production of poultry had a mean score of 3.08 and network service availability had 3.80. Access to internet service and use of personal cell phone to receiving agricultural Information had 3.10 and 3.39 respectively. This indicates poultry farmers in the study area made use of ICT and its facilities on their farms.

Table 3. ICT use by Poultry Farmers in the Study Area

| Usage of ICT facilities | High (4) | Medium (3) | Low (2) | Not at all (1) | Total respondents | Mean score |
|---|---|---|---|---|---|---|
| Use of ICT in your farm practice | 27 | 43 | 9 | 5 | 84 | 3.08 |
| Network service availability | 68 | 16 | - | - | 84 | 3.80 |
| Awareness about mobile Apps | 24 | 33 | 24 | 3 | 84 | 2.92 |
| Access to internet service | 29 | 37 | 16 | 2 | 84 | 3.10 |
| Use of personal cell phone to receiving agricultural Information | 43 | 33 | 7 | 1 | 84 | 3.39 |

Source: Field Survey, 2022.

Access to internet and use of personal mobile phones for accessing agricultural information had mean scores of 3.10 and 3.39 respectively which implied that a slight majority of the poultry farmers had access to internet service as well as used personal cell phones to receive agricultural related information.

**Constraints Associated With ICT Usage by Poultry Farmers**

From Table 4, we may see that about 98.8% of the respondents have a mean score of 1.84 for convenience which implied that convenience of use of ICT facilities would affect adoption by majority of the respondents. The same can be said for other factors such as availability, relative advantage, reliability, educational status, social influence, and cost of the product which had mean scores of 1.58, 1.59, 1.41, 1.34, 1.91, and 1.23 respectively, all of which imply that they would all significantly affect the adoption of ICT facilities among poultry farmers in the study area.

Table 4. Constraints associated with ICT use in the Study Area

| Factors | Yes | Neutral | No | Mean Score |
|---|---|---|---|---|
| Convenience | 41 | 83 | 14 | 1.84 |
| Availability | 57 | 22 | 4 | 1.58 |
| Relative advantage | 50 | 17 | 14 | 1.59 |
| Reliability | 59 | 11 | 12 | 1.41 |
| Educational status | 67 | 12 | 4 | 1.34 |
| Social influence | 30 | 23 | 29 | 1.91 |
| Cost of the product | 71 | 7 | 5 | 1.23 |

Source: Field Survey, 2022.

**Factors affecting ICT use**

The regression result showed a significant $R^2$ value of 0.531 which implies that 53.1% of the variation present in the independent variable was explained by the dependent variables. Four dependent variables such as sex, age, educational level and source of income were significantly affected the use of ICT. Sex and age had negative relationship with the use of ICT and significant at 1% (Table 5).

Table 5. Factors influencing ICT usage by the respondents

| Y | B | Sig | Exp(B) |
|---|---|---|---|
| Sex | -2.652 | .008 | .071 |
| Age | -1.747 | .003 | 0.174 |
| Occupation | .527 | .169 | 1.694 |
| Farming experience in years | 1.014 | .108 | 2.757 |
| Years of schooling | 3.235 | .005 | 25.395 |
| Source of income | 1.366 | .003 | 3.919 |
| Constant | -6.918 | .005 | .001 |

Source: Field Survey, 2022

This indicates that increase in age and sex of the respondents lead to decrease in the usage of ICT facilities in the study area. On the other hand, year of schooling and source of livelihood had positive influence on the usage of ICT facilities among the respondents in the study area.

## CONCLUSIONS

Based on the findings of this study, sex, age, educational qualification and source of income are the key variables and factors that determine the use of ICT by poultry farmers. It can thus be concluded that increased access to ICT facilities is as effective strategy for increasing agricultural productivity particularly poultry production generally as well as the fact that high cost of ICT facilities is a major constraint associated with ICT use among poultry farmers and its applications on poultry farms. Based on the findings of this research, it is recommended that relevant policies aimed at improving agricultural productivity should ensure farmers have adequate access to ICT facilities. Extension workers should also help to improve farmer's knowledge and skills of ICT facilities to enhance adoption of ICT facilities by farmers and thus improve productivity.

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# IMPACT OF FOREIGN CAPITAL ON THE ECONOMIC EFFICIENCY OF FOOD INDUSTRY ENTERPRISES IN THE SLOVAK REPUBLIC

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***Abstract***

*The paper is aimed at assessing the economic efficiency of food industry enterprises based on the foreign capital indicator. The decisive emphasis was placed on the hypothesis that, within the economic efficiency of groups of companies with and without foreign capital, companies with foreign capital would be more efficient. This hypothesis was not confirmed in the 2020 calculations, as some enterprises without foreign capital also achieved comparable or better results compared to groups of enterprises with foreign capital. Given that the calculation of the economic efficiency of food enterprises by the method of classifying groups of enterprises was carried out for the first time, we therefore consider the result to be a preliminary finding.*

***Key words***: *food industry, foreign capital, economic efficiency*

## INTRODUCTION

Foreign investments complete the domestic investments, being a booster for economic development both at the macro and micro level in all the fields of activity, including agriculture and food industry, creating facilities for capital growth, new jobs, production increase and new financial flows to the budget. Also, they allow a higher contribution to GDP and diminish the gap of competitiveness among various countries [4, 10, 11].

Slovakia's accession to the EU opened up greater opportunities for foreign investors. Foreign capital gradually entered the crucial production branches of the food industry.

The inflow of foreign capital invested in the territory of Slovak Republic slowed down in the first half of 1995 due to various non-economic effects. The development later showed that this was rather a transitional, waiting period for foreign investors. At the end of 1995, the volume of foreign capital invested in the Slovak Republic amounted to SKK 21.9 billion. The year-on-year increase was SKK 5.3 billion, of which SKK 4.4 billion (i.e. 82 %) was realized in the second half of the year [2]. According to [5] "the total amount of foreign capital contributed, Austria, Germany, Czech Republic and USA were the largest investors in 1995. The shares of these countries in the total volume of foreign capital in the Slovak Republic range from 12.4% (USA) to 23.4% (Austria) and together they represent approximately 70% of the total volume of foreign capital in the Slovak Republic".

The UK, Netherlands, France, Sweden and Italy follow with larger shareholdings (between 5.7 % and 2.2 % of the total). The shares of other countries whose capital operates in the territory of Slovak Republic did not exceed 1% of the total volume [8].

In the sectoral structure of foreign investment, in 1995 the industrial sector came first. The share of industry in the total volume of foreign capital in the Slovak economy reached 43.4% at the end of the year, followed by trade with 32.4% and in third place with a share of 15.7% was the financial sector. In the regional distribution, the capital City of Bratislava maintains its priority position with a share of 62.1%. In 1995 there was also some intensification of investment flows to regions with a previously low share of foreign capital and high unemployment rates [7].

The use of capacities for the production of chocolate and non-chocolate confectionery and durable pastries is influenced by the presence of foreign investors who have ensured the involvement of their Slovak acquisitions in global distribution systems [6].

According to [8], "there were considerable foreign investments in the dairy sector: there were eight different international dairy farms on the Slovak market: Sole, Italy; Meggle, Germany; Bongrain, Danone and Fromageries Bel, France; Artax, Austria; Friesland Coberco, Netherlands; and Amine Aour, Lebanon. A 2003 report by the Slovak Dairy Association states that 77% of the milk purchased in Slovakia was processed in dairy companies with foreign owners".

Several foreign companies gradually joined the dairy industry, their emergence was initially very strong, but some of them gave up the competition and gradually left Slovakia (Italian Sole, Dutch Friesland, French Danone, Czech Ollma Olomouc, and Lebanese Milex Galanta). Later in Slovakia, french companies Bongrain, Bel and Senoble, German Meggle and Austrian Lactoprot were operating. Dairy farms with foreign capital accounted for 20 % of the total number of dairy farms in 2009 and their share has increased since 2000. This group of companies has been consistently loss-making for a long time. On the other hand, a group of dairy farms without foreign capital improved the profit and was loss-making only in 2002-2003 compared to 2000. All foreign capital companies together produced products for € 225.5 million, which was 49% of the industry´s total output. Compared to 2000, the production of the products of this group increased, but this was a decrease compared to 2007-2008. From the added value of the sector, companies with foreign capital created 44.6 %, while its value increased by 2.2 times compared to 2000, while in enterprises without foreign capital 1.3 times [6].

According to media sources, two foreign investors started buying and grouping up domestic bakeries - the Delta Bakery Group, which is controlled by Luxembourg´s United Bakerie (e.g. Peza, Bratislava´s First Bakery...) and Czech Agrofert. They currently own a network of several bakeries. The bakery´s daughter of Agrofert - Penam Slovakia also owns several mills - (Bratislava, Trnava, Trebišov, Ivanka near Nitra). The company also expanded into Hungary, as its acquisition activity in the Czech Republic and Slovakia is limited by high market shares (problem with antitrust authorities) [5]. In addition, Slovak bakery leaders include Vamex, which has the latest technologies (it produces 24,000 rolls per hour while serving 3 workers). In the opinion of the owner of Vamex, the future of the bakery industry is in large-capacity operations with automation of production. Smaller plants for specialised manual production, which does not pay off for large factories (e.g. Christmas bread), also have a perspective, provided that they cooperate with large enterprises that could outsource this segment of production, which is not promising for them in terms of production costs, but customers are interested in it [8].

The restructuring changes concerned not only the use of human resources, but also the number of enterprises, which was decreasing in the poultry and freezer sectors. This was reflected in the increase in their concentration, which is currently at a high level in these sectors and at a medium level in the canning sector [9]. The increasing share of foreign capital in the fixed capital, mainly in the poultry and freezer sectors, also contributed to this development. On the contrary, its significant decrease was in the canning sector, which was due to the departure of foreign investors from the Slovak market in 2011 [1].

Slovakia´s accession to the EU and globalisation processes have brought the entry of multinational retail chains that import many competing food of foreign origin to Slovakia, which on the one hand motivates producers to produce as efficiently as possible and gives them the possibility to expand sales, including entry into the foreign market and a high standard of sales of their products, but downward pressure on prices causes a decrease in the performance of the agri-food sector and an increase in the share of substitutable commodities in the overall agri-food imports, which has increased since 2002 [7]. According to [3] "in 2006 the most economically efficient were the fish processing, sugar, starch and canning sectors.

The meat, poultry and bakery sectors have worsened their position in terms of economic efficiency".

## MATERIALS AND METHODS

This paper aimed to examine the economic efficiency of groups of enterprises with and without foreign capital, sorted further according to two criteria, either economic prosperity (profitable and loss-making enterprises) or by the size of enterprises (small, medium and large enterprises).

The source of data to assess the impact of foreign capital in food industry enterprises was the Ministry of Agriculture and Rural Development.

An analysis was carried out using basic economic indicators. Emphasis was placed on groups of sorting of enterprises in the food industry of the Slovak Republic depending on the ownership or non-ownership of foreign capital. As part of this, there were two groupings of enterprises, both in terms of economic prosperity (profitable and loss-making enterprises) and in terms of size groups of enterprises according to the number of employees: small enterprises (0-49 employees), medium-sized enterprises (50-249 employees) and large (250 employees and more) enterprises.

a) In assessing economic efficiency from a community-wide point of view the following three indicators were selected:

- the share of value added in yields = value added / revenue;
-the productivity of labour from value added = value added / staff;
- the productivity of total capital = returns / total capital.

b) In assessing economic efficiency from a private-ownership point of view, the following five indicators were selected:

- the share of value added in yields = value added / revenue;
- the financial labour productivity = added value / personnel costs;
- the productivity of total capital = total capital / returns;
-the return on equity = profit / equity;
- the profitability = profit / revenue.

c)The following indicators were used in the classification of enterprises by economic creditworthiness:

- the cash liquidity = (short-term receivables + financial accounts) / short-term liabilities;
- the self-financing indicator = equity / total capital;
- the cash flow indebtedness indicator = total liabilities / (depreciation + profit).

Using the standard variable method, the order of the sorting groups was determined as follows:

In a file that had n members and an X indicator that acquired xi (i = 1.2,...,n) for each member of the file. The X indicator has been normalized to the indicator:

$$z_i = \frac{x_{i-\bar{x}}}{S_x} \quad \text{.........................} \quad (1)$$

where the average has been calculated according to the relationship:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad \text{.........................}(2)$$

and standard deviation according to the relationship:

$$s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad \text{...................}(3)$$

While the original X-indicators could be in any unit of measurement (persons, euros, euros per person, etc.), the measuring unit of the standardized indicators ′′Z′′ is a standard deviation and in this sense they are to some extent similar.

The standard values Z1, Z2 and Z3 (respectively Z1, Z2, Z3, Z4 and Z5) were calculated from the values of relative indicators and corresponding averages and standard deviations, and their sum resulted in a synthetic indicator according to which the sorting groups were ranked according to the achieved efficiency.

## RESULTS AND DISCUSSIONS

Foreign capital stood at €537 million in 2010. The volume of funds from abroad has had significant fluctuations over the years, especially in 2013, but so far it has been maintained at above €400 million and is located in 9.4% of food companies. Its share in total assets is also on a downward trend, in 2010 from 62.6% to 50.3%, in 2020, i.e. by 12.3%. There was a similar development in its share in equity, which reached 15.7% in the last evaluated year, which was 3.1 % lower than in 2010. This development was influenced by the departure of several foreign investors from the Slovak Republic. Not only large investors were leaving, but also small and medium-sized enterprises, even for lower taxes. In the food industry, there was also a regrouping of owners by selling companies. Strong domestic financial groups have shown interest in food industry. The biggest changes in previous years took place in the meat industry, dairy and brewing. The number of foreign equity enterprises in 2020 (36, i.e. 9.4 %) is the lowest during the 10-year period, but not only the departure of investors has been noted, but also the arrival of new foreign investors, but with lower capital than in the previous period (Table 1).

The highest share of foreign capital in equity at present is in the starch industry, on the contrary, in the meat, milling, freezing and fisheries industries foreign capital was absent in 2020. Although in most of the previous years (until 2018), foreign capital (excluding the freezer industry) was present in these sectors.

Table 1. Development of foreign capital (in million €) and its share on assets in food industry (in %)

| **Indicator** | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Foreign capital (in million €)** | 537 | 531 | 476 | 400 | 435 | 490 | 483 | 512 | 468 | 439 | 432 |
| **Share of foreign capital on capital stock (in %)** | 62.6 | 62.0 | 59.7 | 55.3 | 59.2 | 65.7 | 59.8 | 62.8 | 59.2 | 51.7 | 50.3 |
| **Share of foreign capital on total assets (in %)** | 19.8 | 19.4 | 16.9 | 13.3 | 13.8 | 15.9 | 16.2 | 16.0 | 15.8 | 15.6 | 15.7 |

Source: processed by authors, based on the data of Research Institute of Agricultural and Food Economics.

Within a group of enterprises sorted by size (number of employees), the most foreign capital was concentrated in large (67%) and medium-sized (30 %) enterprises. In terms of economic prosperity, 72% of foreign capital was in profitable enterprises.

In 2020, less than 10% of foreign capital enterprises achieved 42% of the total sector´s production of products as well as value added (the remainder, i.e. 58% for enterprises without foreign capital).

Almost 73 % of the total charges for supplies to the food business network were paid by foreign capital enterprises (Table 2).

As part of exports (shipment of goods to EU Member States plus exports of goods to non-EU countries), foreign capital enterprises exported up to 66% of the industry´s total goods.

Within exports (within the EU and outside the EU), exports (dispatch of goods) to EU member states predominated both in the group of enterprises with foreign capital (93%) and in the group of enterprises without foreign capital (95%).

**Economic prosperity of food enterprises and enterprises by size**

From the point of view of classifying enterprises according to economic prosperity (profitable and loss-making enterprises), it follows that most of the production of related indicators in financial terms (production of products, added value, turnover) was achieved by profitable enterprises (in a group of enterprises with foreign as well as without-foreign capital).

Table 2. Selected economic indicators and delivery fees into retail chain in absolute terms (in million €)

| Sorting group | Production | Value added | Revenues from own products and services | Revenues from goods sale | Goods shipping to EU member countries | Goods export to non-member countries of the EU | Delivery fees into retail chain |
|---|---|---|---|---|---|---|---|
| **Enterprises without foreign capital in total, therein:** | **1,605** | **385** | **1,534** | **425** | **319** | **18** | **55** |
| - profitable | 1,222 | 314 | 1,165 | 357 | 253 | 12 | 37 |
| - loss- making | 383 | 70 | 369 | 68 | 66 | 6 | 18 |
| - small | 253 | 56 | 248 | 61 | 40 | 4 | 5 |
| - medium | 838 | 189 | 788 | 188 | 159 | 10 | 30 |
| - large | 513 | 140 | 497 | 175 | 120 | 3 | 21 |
| **Enterprises with foreign capital in total, therein:** | **1,178** | **281** | **1,184** | **517** | **598** | **45** | **148** |
| - profitable | 958 | 261 | 953 | 338 | 463 | 25 | 139 |
| - loss- making | 221 | 20 | 231 | 179 | 134 | 20 | 9 |
| - small | 32 | 7 | 35 | 14 | 16 | 0 | 5 |
| - medium | 432 | 75 | 443 | 236 | 353 | 36 | 14 |
| - large | 714 | 199 | 706 | 267 | 229 | 9 | 129 |
| Share of enterprises without foreign capital of the sector (in %) | 58 | 58 | 56 | 45 | 35 | 28 | 27 |
| Share of enterprises with foreign capital from the sector (in %) | 42 | 42 | 44 | 55 | 65 | 72 | 73 |
| **Food industry of the Slovak Republic in total** | **2,783** | **665** | **2,717** | **942** | **917** | **63** | **204** |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

Within the classification of enterprises according to the size of the number of employees in the group of enterprises without foreign capital, medium-sized enterprises (product production) dominated more than half, large enterprises contributed more than a third and the rest fell on small (about 15-16 %) enterprises. In the group of enterprises with foreign capital, production was dominated by large enterprises (60-70%), a third by medium-sized enterprises and less (by less than 3%) by small enterprises.

In terms of percentages, the results were similar for both the export indicator and the delivery fees into retail chain indicator, namely, in both groups of companies, with foreign and without foreign capital, there was a higher share of profitable enterprises as loss-making. In terms of enterprises sorted by size in a group of enterprises without foreign capital (export indicator and delivery fees into retail chain indicator), more than half of medium-sized enterprises dominated, followed by large enterprises and the rest fell to small enterprises. In the group of companies with foreign capital, the exports were dominated by medium-sized enterprises and followed by large enterprises, with the delivery fees into retail chain indicator 87 % paid by large enterprises, the medium-sized only 9 %. From the production of food products export (dispatch of goods to the EU plus exports to third countries) accounted for 35 %. Enterprises without foreign capital exported 21 % from their own production of products and companies with foreign capital 54 %. Within the structure of enterprises without foreign capital, the groups contributed to the export of their production as follows: profitable 22 %, loss-making 19 %, small 17 %, medium-sized 20 %, and large 24 % (Table 3).

Table 3. Selected economic indicators and delivery fees into retail chain in percentage terms

| **Sorting group** | **Production** | **Value added** | **Revenues from own products and services** | **Revenues from goods sale** | **Goods shipping to EU member countries** | **Goods export to non-member countries of the EU** | **Delivery fees into retail chain** | **Goods shipping + export in total** |
|---|---|---|---|---|---|---|---|---|
| **Enterprises without foreign capital in total, therein:** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |
| - profitable | 76 | 82 | 76 | 84 | 79 | 65 | 67 | 78 |
| - loss- making | 24 | 18 | 24 | 16 | 21 | 35 | 33 | 22 |
| - small | 16 | 15 | 16 | 14 | 12 | 25 | 9 | 13 |
| - medium | 52 | 49 | 51 | 44 | 50 | 59 | 54 | 50 |
| - large | 32 | 36 | 32 | 41 | 38 | 16 | 38 | 36 |
| **Enterprises with foreign capital in total, therein:** | **100** | **100** | **100** | **100** | **100** | **100** | **100** | **100** |
| - profitable | 81 | 93 | 80 | 65 | 78 | 56 | 94 | 76 |
| - loss- making | 19 | 7 | 20 | 35 | 22 | 44 | 6 | 24 |
| - small | 3 | 2 | 3 | 3 | 3 | 0 | 4 | 3 |
| - medium | 37 | 27 | 37 | 46 | 59 | 80 | 9 | 61 |
| - large | 61 | 71 | 60 | 52 | 38 | 20 | 87 | 37 |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

Within the framework of the structure of enterprises with foreign capital, exports in the production of products participated as follows in groups of enterprises:
- profitable 51 %,
- loss-making 70 %,
- small 50 %,
- medium-sized 90 %,
- large 33%.

This means that profitable companies with foreign capital exported 51 % of their production.

Both groups of enterprises, with and without foreign capital, achieved a positive economic result, but in the group of companies with foreign capital represented up to 63 % of the level of the food sector, in case of the companies without foreign capital it was 37 % of the level of the food sector.

Table 4 presents economic and social indicators in absolute terms.

Enterprises without foreign capital predominate with a share of around 70% in the number of employees as well as in procured investments.

Table 4. Economic and social indicators in absolute terms (million €, employees as persons)

| Sorting group | Profit/loss before taxation | Average registered number of employees | Therein: technical and administrative employees | Difference employees - technical and administrative employees | Sourced investments in total | Foreign capital | Obligations to primary production |
|---|---|---|---|---|---|---|---|
| **Enterprises without foreign capital in total, therein:** | **38** | **21,580** | **3,741** | **17,839** | **113** | **0** | **49** |
| - profitable | 58 | 16,337 | 2,856 | 13,481 | 95 | 0 | 32 |
| - loss- making | -20 | 5,243 | 885 | 4,358 | 17 | 0 | 16 |
| - small | 3 | 3,696 | 751 | 2,945 | 24 | 0 | 9 |
| - medium | 26 | 11,155 | 1,872 | 9,283 | 41 | 0 | 33 |
| - large | 8 | 6,729 | 1,118 | 5,611 | 48 | 0 | 7 |
| **Enterprises with foreign capital in total, therein:** | **63** | **7,432** | **2,628** | **4,804** | **52** | **432** | **42** |
| - profitable | 88 | 5,796 | 2,208 | 3,588 | 44 | 313 | 21 |
| - loss- making | -25 | 1,636 | 420 | 1,216 | 8 | 119 | 22 |
| - small | -4 | 232 | 102 | 130 | 2 | 13 | 1 |
| - medium | 14 | 1,822 | 567 | 1,255 | 16 | 128 | 22 |
| - large | 53 | 5,378 | 1,959 | 3,419 | 34 | 291 | 19 |
| Share of enterprises without foreign capital of the sector (in %) | 37 | 74 | 59 | 79 | 68 | 0 | 53 |
| Share of enterprises with foreign capital from the sector (in %) | 63 | 26 | 41 | 21 | 32 | 100 | 47 |
| **Food industry of the Slovak Republic in total** | **100** | **29,012** | **6,369** | **22,643** | **165** | **432** | **91** |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

Table 5 presents economic and social indicators in percentage terms.

The shares in primary production liabilities are relatively balanced between the two groups of enterprises (without and with foreign capital). In the group of enterprises by size, the group of medium-sized enterprises without foreign capital has the largest share of liabilities to primary production (69 %). And in case of large and small enterprises the shares are less than 20 %. In enterprises with foreign capital medium-sized enterprises have the share of liabilities to primary production at the level of 52 %, while large enterprises achieved a share of 45 % and small enterprises only 3 %.

Table 5. Economic and social indicators in percentage terms (%)

| Sorting group | Average registered number of employees | Therein: technical and administrative employees | Difference employees – technical and administrative employees | Sourced investments in total | Foreign capital | Obligations to primary production |
|---|---|---|---|---|---|---|
| **Enterprises without foreign capital in total, therein:** | **100** | **100** | **100** | **100** | **-** | **100** |
| - profitable | 76 | 76 | 76 | 85 | - | 66 |
| - loss- making | 24 | 24 | 24 | 15 | - | 34 |
| - small | 17 | 20 | 17 | 21 | - | 18 |
| - medium | 52 | 50 | 52 | 36 | - | 69 |
| - large | 31 | 30 | 31 | 43 | - | 14 |
| **Enterprises with foreign capital in total, therein:** | **100** | **100** | **100** | **100** | **100** | **100** |
| - profitable | 78 | 84 | 75 | 85 | 72 | 49 |
| - loss- making | 22 | 16 | 25 | 15 | 28 | 51 |
| - small | 3 | 4 | 3 | 4 | 3 | 3 |
| - medium | 25 | 22 | 26 | 30 | 30 | 52 |
| - large | 72 | 75 | 71 | 66 | 67 | 45 |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic

**Economic efficiency from a societal point of view**

In 2020, a group of large enterprises without foreign capital (Y) worked most socially effective. The second and third best ranked were groups of profitable foreign capital enterprises and large companies with foreign capital.

Table 6. Sorting groups of food industry in the Slovak Republic for the year 2020; economic efficiency from societal aspect

| Sorting groups of food industry in the Slovak Republic | Share of value added in yields in € | Labour productivity from value added in € | Productivity from total capital in € | Z1 | Z2 | Z3 | Y |
|---|---|---|---|---|---|---|---|
| - large enterprises without foreign capital | 0.19 | 20,756 | 1.57 | 1.23 | 1.23 | 1.40 | 3.86 |
| - profitable enterprises with foreign capital | 0.20 | 44,955 | 1.62 | 0.97 | 0.94 | 0.49 | 2.39 |
| - large enterprises with foreign capital | 0.20 | 37,006 | 1.86 | 1.01 | 0.33 | 0.96 | 2.30 |
| - profitable enterprises without foreign capital | 0.19 | 19,235 | 1.38 | 0.71 | 0.72 | 0.42 | 1.85 |
| - enterprises with foreign capital in total | 0.16 | 37,759 | 1.56 | 0.42 | 0.39 | 0.38 | 1.18 |
| - enterprises without foreign capital in total | 0.18 | 17,818 | 1.33 | 0.28 | 0.24 | 0.16 | 0.68 |
| - medium enterprises with foreign capital | 0.11 | 41,205 | 1.45 | -0.40 | 0.65 | 0.17 | 0.42 |
| - medium enterprises without foreign capital | 0.17 | 16,910 | 1.30 | -0.06 | -0.07 | 0.02 | -0.11 |
| - small enterprises with foreign capital | 0.12 | 28,154 | 0.51 | -0.22 | -0.35 | -1.68 | -2.24 |
| - small enterprises without foreign capital | 0.16 | 15,211 | 1.06 | -0.61 | -0.64 | -1.21 | -2.45 |
| - loss-making enterprises with foreign capital | 0.05 | 12,267 | 1.40 | -1.36 | -1.57 | 0.06 | -2.87 |
| - loss-making enterprises without foreign capital | 0.15 | 13,404 | 1.17 | -1.27 | -1.25 | -0.64 | -3.15 |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

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The lowest efficiency from a social point of view in 2020 (in turn) was achieved by a group of loss-making enterprises without foreign capital, followed by a group of loss-making enterprises with foreign capital and small enterprises without foreign capital (Table 6).

**Economic efficiency from a private ownership point of view**

Taking into account indicators reflecting the private ownership aspect, the most effective in 2020 was managed by a group of profitable enterprises with foreign capital, followed by groups of large enterprises with foreign capital and profitable enterprises without foreign capital.

Table 7. Sorting groups of food industry in the Slovak Republic for the year 2020; economic efficiency from private ownership aspect

| Sorting groups of food industry in the Slovak Republic | Share of value added in yields in € | Financial labour productivity in € | Productivity of total capital in € | Return on equity in € | Profitability in € | Z1 | Z2 | Z3 | Z4 | Z5 | Y |
|---|---|---|---|---|---|---|---|---|---|---|---|
| - large enterprises without foreign capital | 0.20 | 3.14 | 1.62 | 0.21 | 0.07 | 0.97 | 0.91 | 0.49 | 0.92 | 1.02 | 4.31 |
| - profitable enterprises with foreign capital | 0.20 | 2.73 | 1.86 | 0.22 | 0.05 | 1.01 | 0.43 | 0.96 | 1.00 | 0.81 | 4.20 |
| - large enterprises with foreign capital | 0.19 | 2.25 | 1.38 | 0.11 | 0.03 | 0.71 | 0.92 | 0.42 | 0.82 | 0.91 | 3.78 |
| - profitable enterprises without foreign capital | 0.19 | 2.15 | 1.57 | 0.05 | 0.01 | 1.23 | 0.55 | 1.40 | 0.26 | 0.15 | 3.59 |
| - enterprises with foreign capital in total | 0.16 | 2.76 | 1.56 | 0.11 | 0.04 | 0.42 | 0.46 | 0.38 | 0.41 | 0.54 | 2.21 |
| - enterprises without foreign capital in total | 0.18 | 2.09 | 1.33 | 0.06 | 0.02 | 0.28 | 0.30 | 0.16 | 0.38 | 0.35 | 1.47 |
| - medium enterprises with foreign capital | 0.17 | 2.07 | 1.30 | 0.08 | 0.02 | -0.06 | 0.22 | 0.02 | 0.53 | 0.57 | 1.27 |
| - medium enterprises without foreign capital | 0.11 | 2.93 | 1.45 | 0.05 | 0.02 | -0.40 | 0.66 | 0.17 | 0.07 | 0.28 | 0.78 |
| - small enterprises with foreign capital | 0.16 | 2.01 | 1.06 | 0.03 | 0.01 | -0.61 | -0.02 | -1.21 | 0.11 | 0.05 | -1.66 |
| - small enterprises without foreign capital | 0.12 | 1.97 | 0.51 | -0.09 | -0.07 | -0.22 | -0.47 | -1.68 | -0.70 | -1.11 | -4.17 |
| - loss-making enterprises with foreign capital | 0.05 | 1.07 | 1.40 | -0.20 | -0.06 | -1.36 | -1.53 | 0.06 | -1.29 | -1.00 | -5.12 |
| - loss-making enterprises without foreign capital | 0.15 | 1.59 | 1.17 | -0.18 | -0.04 | -1.27 | -1.67 | -0.64 | -1.72 | -1.68 | -6.98 |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

The group of loss-making companies without foreign capital, but also the group of loss-making companies with foreign capital and the group of small companies with foreign capital, performed the least effectively from a private ownership point of view (Table 7).

**Classification of groups by economic creditworthiness**

In terms of the ability to survive economically (to meet its obligations) in 2020 and in terms of ranking, the best group was profitable enterprises without foreign capital, followed by medium-sized enterprises with foreign capital and medium-sized enterprises without foreign capital.

In terms of economic creditworthiness, the worst were managed by loss-making enterprises without foreign capital, small enterprises with foreign capital, small enterprises without foreign capital, large enterprises with foreign capital and loss-making enterprises with foreign capital.

The assumed hypothesis that foreign capital will affect the economic efficiency and creditworthiness of food industry enterprises was not confirmed to a significant extent in 2020, as some groups of food companies without foreign capital also achieved comparable, respectively better results compared to groups of companies with foreign capital (Table 8).

Table 8 Sorting groups of food industry in the Slovak Republic for the year 2020 by creditworthiness

| Sorting groups of food industry in the Slovak Republic | Cash liquidity in € | Self-financing indicator in e | Cash flow indebtedness indicator in € | Z1 | Z2 | Z3 | Y |
|---|---|---|---|---|---|---|---|
| - profitable enterprises without foreign capital | 1.40 | 0.43 | 4.69 | 0.98 | 0.94 | 0.53 | 2.45 |
| - profitable enterprises with foreign capital | 1.04 | 0.57 | 5.43 | 1.03 | 1.40 | -0.10 | 2.33 |
| - medium enterprises without foreign capital | 1.29 | 0.41 | 6.08 | 0.57 | 0.68 | 0.45 | 1.70 |
| - large enterprises without foreign capital | 1.29 | 0.40 | 6.04 | 0.57 | 0.43 | 0.45 | 1.45 |
| - profitable enterprises with foreign capital | 0.99 | 0.52 | 2.73 | 0.63 | 0.63 | 0.11 | 1.36 |
| - enterprises with foreign capital in total | 0.90 | 0.50 | 4.25 | 0.02 | 0.31 | -0.01 | 0.33 |
| - enterprises without foreign capital in total | 1.21 | 0.39 | 6.30 | 0.27 | 0.35 | 0.43 | 0.19 |
| - loss-making enterprises with foreign capital | 0.70 | 0.43 | -14.10 | -1.45 | -0.57 | 1.37 | -0.65 |
| - large enterprises with foreign capital | 0.82 | 0.45 | 3.26 | -0.57 | -0.36 | 0.07 | -0.86 |
| - small enterprises without foreign capital | 0.93 | 0.33 | 7.48 | -0.81 | -0.60 | 0.36 | -1.05 |
| - small enterprises with foreign capital | 0.95 | 0.40 | 23.40 | 0.36 | -1.09 | -1.45 | -2.18 |
| - loss-making enterprises without foreign capital | 0.80 | 0.27 | 41.77 | -1.32 | -1.45 | -1.79 | -4.55 |

Source: processed by authors, based on the data of Ministry of Agriculture and Rural Development of the Slovak Republic.

## CONCLUSIONS

Foreign capital was located in 9.4 % of food businesses, which accounted for 50.3 % of their equity. The highest share of foreign capital in equity was in the starch industry, on contrary, in the meat, milling, freezing and fisheries industries foreign capital is absent.

For 2020, the best group of enterprises, taking into account the results of efficiency and at the same time the results of economic creditworthiness, was a group of profitable enterprises without foreign capital.

Despite the fact that large companies with foreign capital managed efficiently, both from a social and ownership point of view, their economic creditworthiness was lower, as they did not have sufficient solvency, i.e. prompt liquidity to cover short-term liabilities.

In each of the three calculations used (from a community-wide point of view, private ownership, economic creditworthiness), loss-making enterprises without foreign capital ranked worst.

According to the hypothesis examined for 2020, the impact of foreign capital on the economic efficiency of food business groups has not been confirmed. It cannot be said unequivocally that foreign capital firms have managed more efficiently than those without foreign capital.

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# MECHANISMS OF STIMULATION OF AGRARIAN SCIENCE FOR THE PURPOSE OF HARMONIZING FEDERAL AND REGIONAL INNOVATION AND INVESTMENT POLICY

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***Abstract***

*Improving the competitiveness of the agro-industrial complex in the context of an imbalance in the global food market and a tough sanctions policy can be achieved by stimulating the innovation and investment activities of regional and sectoral agricultural systems. The purpose of this article is to improve approaches to the optimal distribution of investments in agriculture and to develop tools to stimulate innovation and investment activity. It has been empirically proven that in Russia the priority areas for the use of investment resources are significantly underfunded, which is a blocking factor in increasing the competitiveness and economic growth of the agricultural sector of the economy. New investment mechanisms aimed at further improvement of regional and federal investment policy have been studied. Measures to stimulate innovation and investment activity are proposed and a pool of indicators for assessing indirect effects is substantiated. A mechanism for the development of the agro-industrial complex was developed on the basis of systemic mediation with the substantiation of the functions of an innovative mediator as a link between the institutional actors of the organization. This mechanism makes it possible to increase the efficiency of institutional interaction between the stakeholders of the innovation process, ensures planning and coordination of fundamental and applied research at the federal and regional levels.*

***Key words*:** *innovation, agro-industrial complex, structural transformation, agricultural science, investment resources, system mediation, planning and coordination, harmonization*

## INTRODUCTION

In the context of an imbalance in the global food market and a tough sanctions policy, there is a need to increase the production of domestic agricultural products and develop import substitution. In accordance with the national development goals for the period up to 2030, the task was set to achieve outstripping growth rates of GRP at a level of at least 3% per year and reach indicators above the world average [12]. The task was also set to increase the real growth of investments in fixed assets by at least 70% [2]. However, various factors influence the increase in the efficiency of agriculture, and despite the increase in innovation and investment activity in some regions, stagnation is observed in the industry as a whole in Russia. [20]. The problems of increasing innovation and investment activity and the impact of investment resources on accelerating the structural transformation of the agrarian economy are based on the works of classical economic theory and modern conceptual approaches, the priority tasks of the country for a specific period of time. The theoretical and methodological foundations of the study were laid in the theory of capital, economic growth, economic cycles. Among the founders, it should be noted J. Keynes, K. Marx, J. Stiglitz, J. Harcourt, I. Schumpeter, A. Damodaran, A. G. Aganbegen, I. A. Clark, S. Yu. Glazyev and others. organizational conditions for stimulating innovative development are based on increasing the effectiveness of interaction between institutions of government, science, business, marketing and information support in the process of creating, implementing, distributing and commercializing domestic innovative solutions [7].

In foreign countries, a model of interaction based on systemic innovative mediation has become widespread. "Systemic innovation intermediary" is an organization that functions between various innovation actors, facilitating and coordinating innovation activity at the system level [6]. The system innovation intermediary is capable of stimulating innovation and investment development, is aimed at smoothing out the weaknesses of the innovation system, thus ensuring the acceleration of innovation [8, 9].

## MATERIALS AND METHODS

The purpose of the study is to develop methodological approaches to improving the mechanisms for stimulating agricultural science in order to harmonize federal and regional innovation and investment policies.

The methodological basis of the study was legal documents, studies of foreign and Russian scientists on investment activity, the formation and use of investment resources in agriculture and the agro-industrial complex as a whole. In order to implement innovative structural transformations of the agricultural sector, such methods as monographic, abstract-logical, analytical, economic-statistical and expert methods were used.

The information base for the analysis was the statistical data of Rosstat, the Higher School of Economics, the Ministry of Agriculture on innovation, research activities in agriculture, the financing of agricultural science; expert research materials.

## RESULTS AND DISCUSSIONS

In modern geopolitical conditions and sanctions policy there is a need for an in-depth study of the processes of formation and use of investment resources in the agro-industrial complex. One of the most important indicators for assessing innovation and investment activity is the indicator of the share of gross capital formation.

Fig.1. shows the dynamics of the share of gross capital formation in GDP is presented on the example of the USA, Russia, India, China, Korea.

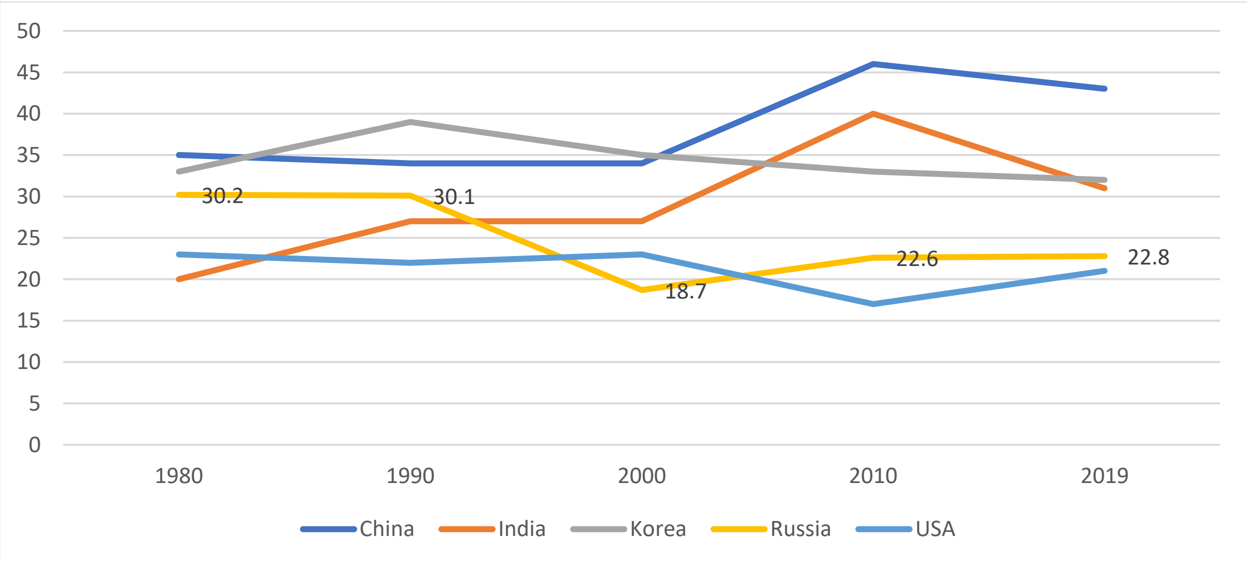


Fig. 1. Dynamics of the share of savings in GDP in various countries in 1980–2019, in %
Source: Own calculations based on data [14].

It can be seen that this indicator in China, Korea and other Asian countries remains at a fairly high level - about 30%. In Russia, this indicator has decreased compared to the earlier period and is now at a low level [10].

According to Maslova V.V., investment capital is formed from non-financial and financial investments.

These include investments in technology, machinery, equipment, productive livestock, intellectual property, non-produced non-financial assets, as well as long-term investments in bank deposits, stocks, securities, and other instruments [11].

An analysis of the level of funding for scientific research and their share in investment expenditures showed a value of 0.7% in the economy as a whole, and 0.003% in agriculture, which shows a huge gap and lagging behind agriculture from general economic indicators.

These values show a significant level of underfunding of strategic directions for the use of investment capital both in the economy as a whole and especially in agriculture [5].

An analysis of the personnel potential of agricultural science showed that in 2010–2020. there was a significant reduction (Fig. 2).

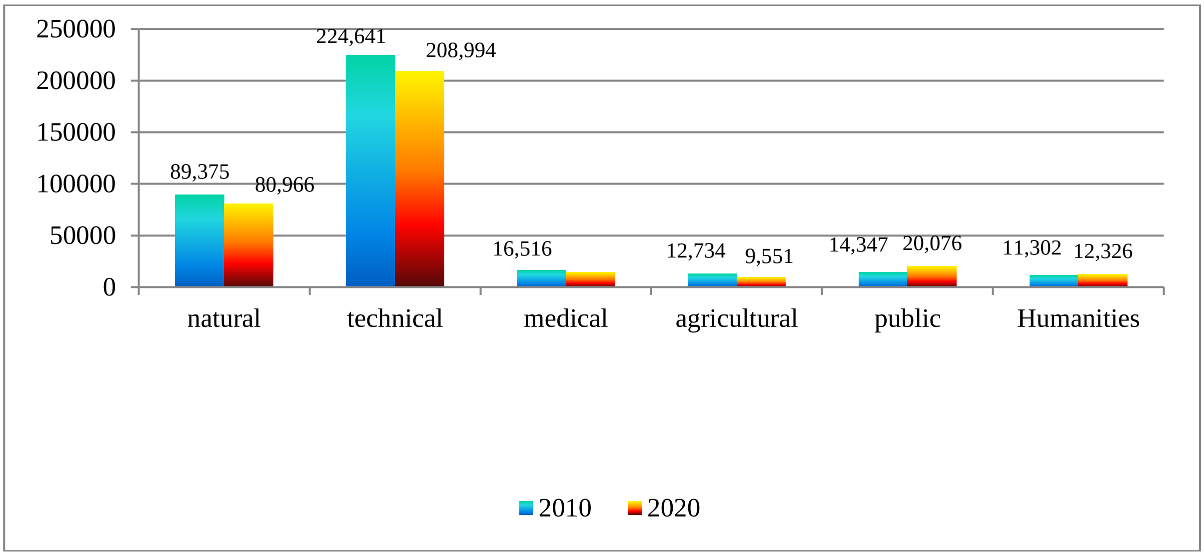


Fig. 2. Dynamics of the number of Russian researchers by fields of science (persons)
Source: Own calculations based on Rosstatdata [19].

The number of research scientists in agriculture over the past ten years has decreased by a quarter and amounted to less than 10 thousand people.

According to statistics, less than a third of the scientific organizations of the Ministry of Agriculture are engaged in research and development, 30–40 times less funding is allocated per organization compared to other areas of science. [4].

As agriculture is a highly labor intensive sector, productivity level in negatively influenced by labour input data while gross value added has to be intensified to contribute to the growth of agricultural output and gross value added [1,15,16]. A significant deterioration in the conditions for financing Russian agricultural science confirms the ratio of government spending on agricultural science and the value added of agriculture. In such developed countries as the USA, Denmark, Austria, this figure ranges from 2.65% to 3.38%; in Russia - 0.37% [17].

Thus, the development of the scientific potential of the agricultural sector is largely constrained by the low scale of financing of agricultural sciences, which has a direct impact on the intensity of innovation processes in agriculture (Fig. 3).

Along with the low level of funding for scientific research, the innovative development of agriculture is significantly constrained by such factors as the weak interest of business in financing long-term projects; insufficient level of state support compared to advanced agricultural countries, low level of implementation of digital technologies, artificial intelligence and machine learning technologies.

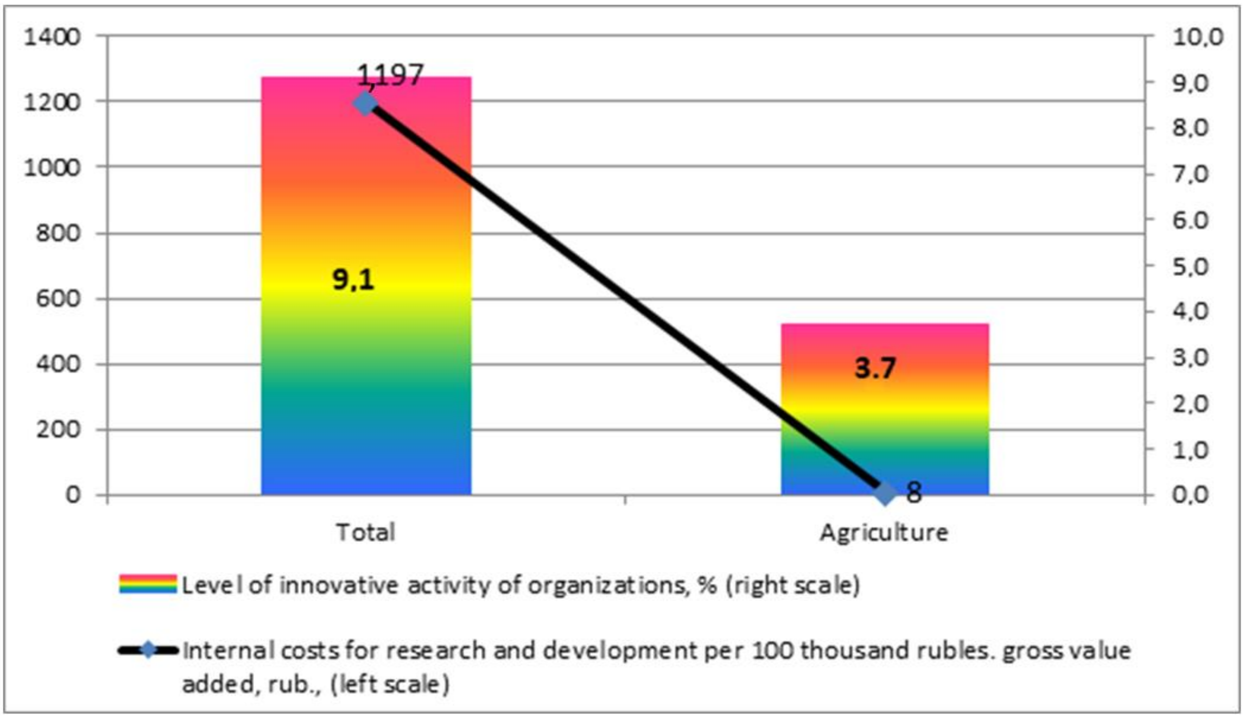


Fig. 3. The ratio of specific internal costs for research and development and the level of innovative activity of Russian organizations (2019)
Source: Own calculations based on data [18].

The agro-industrial complex is characterized by a pronounced inter-regional differentiation in the spread of innovations; regions often compete with each other for the location of high-tech companies.

The formation of an export-oriented agricultural sector of the economy predetermines the need to improve the innovation and investment policy based on the harmonization of management mechanisms at the federal and regional levels.

In the National Plan of Action to ensure the restoration of employment and incomes of the population, economic growth and long-term structural changes in the economy (National Plan), new investment mechanisms were proposed to further improve regional and federal investment policies based on the principles of strategic planning [21].

An assessment of fundamentally new investment instruments made it possible to identify the possibility of observing the principles of planning, coordination, flexibility, maneuverability and preventive action in the ongoing federal and regional investment policy (Table 1).

The new investment policy measures are aimed at accelerating the technological development of the economy and require enhanced government support.

The study implemented the following hypothesis: achieving harmonization of federal and regional investment policies is possible subject to the principles of strategic planning.

An assessment of the new instruments of federal and regional investment policy showed their compliance with the principles of planning, coordination, flexibility, maneuverability and preventive action.

It should be noted the important role in achieving the harmonization of the federal and regional investment policy of such instruments as the use of the «investment standard» in the formation of portfolios of investment projects in the regions; redistribution of budget funds for financing capital investments.

To assess the effectiveness of the proposed measures, indicators of indirect investment effects (improving the quality of investments, increasing innovative activity, economic growth) can be used [22, 23].

Table 1. Evaluation of new instruments of federal and regional investment policy reflected in the National Plan

| List of Investment Instruments of the National Plan | Compliance of federal and regional investment policy with the goal-setting principles of strategic planning |
|---|---|
| 1. Creation of a legal and regulatory framework to increase the investments of companies with state participation, which are under the jurisdiction of the sector | Planning and coordination |
| 2. Introduction of a mechanism for the implementation of special investment contracts | Planning and coordination |
| 3. Formation of a «starting» portfolio of investment projects | Flexibility, coordination |
| 4. Development of project financing tools for the investment phase of projects | Planning and coordination |
| 5. Creation of an information and analytical system for supporting investment processes in the Russian Federation, including regional investment projects | coordination, flexibility |
| 6. Formation of portfolios of investment projects of the regions using the «investment standard» | Planning and coordination |
| 7.Accelerated development and support of technology companies | Planning and coordination |
| 8. Mechanisms for promoting the implementation of investment programs of companies with state participation | Coordination |
| 9. Redistribution of budgetary funds to finance capital investments | Flexibility, coordination, agility |
| 10. Advanced construction of objects of regional (municipal) property on the terms of co-financing from the federal budget | Prevention, coordination, maneuverability |

Source: Own calculations based on [13].

In order to increase the competitiveness and investment attractiveness of the agro-industrial complex, the article developed a mechanism for stimulating the innovative and investment development of the agro-industrial complex based on systemic mediation with the rationale for the functions of an innovative mediator as a link between the institutional actors of the organization.

This mechanism makes it possible to increase the efficiency of institutional interaction between the stakeholders of the innovation process, ensures planning and coordination of fundamental and applied research at the federal and regional levels. Systemic mediation predetermines the formation of a collaborative innovative culture of society, which increases the interpersonal and institutional level of trust in society [3].

Under these conditions, the creation of a systematic innovation intermediary, functioning as a coordinator between the actors of the innovation and investment process and performing unique functions, will stimulate the introduction of advanced scientific achievements in agricultural production.

The mechanism of innovative mediation is intended for information and consulting support of commodity producers, training of highly qualified personnel, increasing the efficiency of scientific research, and expanding the integration of agricultural science and production. High innovative activity will promote economic growth in the agro-industrial complex of Russia, increase the competitiveness of commodity producers in domestic and foreign markets.

Considering the need to provide agriculture with its own veterinary drugs and other resources; development and implementation of domestic technologies, one of the most important tasks of system innovation mediation is the creation of equal conditions for competition for all forms of management. Increasing the innovative activity of small and medium-sized businesses will help ensure the economic growth of the Russian agro-industrial complex, increase the competitiveness of commodity producers, develop rural areas, produce quality food, increase the economic potential of the industry and its competitiveness in foreign markets.

## CONCLUSIONS

The study developed methodological approaches to stimulating innovation and investment development based on the improvement of economic and organizational conditions. The analysis of the processes of formation and use of investment resources in the agro-industrial complex has been carried out. The problems, trends and drivers of the innovative development of the agro-industrial complex are identified. It is substantiated that in Russia the priority areas for the use of investment resources are significantly underfunded, which is a blocking factor in increasing the competitiveness and economic growth of the agricultural sector of the economy. An analysis of the level of funding for scientific research and their share in investment expenditures showed a huge gap and lagging behind agriculture from general economic indicators and indicates a significant underfunding of strategic directions of development. The factors hindering innovation and investment development are identified: weak interest of business in financing long-term projects: gap between the creation and implementation of new ideas and technological solutions; insufficient government support for promising innovative projects. The necessity of observance of the principles of planning, coordination, flexibility, maneuverability and preventive action in the ongoing federal and regional investment policy is substantiated. The following hypothesis is implemented in the work: it is possible to achieve harmonization of federal and regional investment policy, provided that the principles of strategic planning are observed. Measures to stimulate innovation and investment activity are proposed and a pool of indicators for assessing indirect effects is substantiated. A mechanism for the development of the agro-industrial complex was developed on the basis of systemic mediation with the substantiation of the functions of an innovative mediator as a link between the institutional actors of the organization. This mechanism makes it possible to increase the efficiency of institutional interaction between the stakeholders of the innovation process, ensures planning and coordination of fundamental and applied research at the federal and regional levels.

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# IMPROVING METHODOLOGICAL APPROACHES TO FINANCING AGRARIAN SCIENCE TO STIMULATE INNOVATIVE AGRICULTURAL PRODUCTION

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***Abstract***

*In modern conditions, the problem of improving the mechanism of state support for innovative agricultural production is actualized. The purpose of the study is to evaluate the effectiveness of financing agricultural science and develop a mechanism for stimulating innovative agricultural production. The article analyzes the impact of investments on the innovative development of agricultural systems based on the construction of models of the modified Cobb-Douglas production function, substantiates methodological approaches to financing agricultural science to increase incentives. for innovative agricultural production. Foreign and domestic theoretical and methodological approaches to the financing of agricultural science have been studied. Empirically, calculations were made to determine the optimal level of financing of agricultural science in order to reduce interregional differentiation. It has been empirically proven that the process of financing scientific research in the field of agricultural sciences does not sufficiently influence the dynamics of production volumes. Approaches have been developed to optimize the means of financing agricultural science on the basis of the achieved criterion of innovativeness of production. The practical significance of the results of this work lies in the improvement of tools for stimulating innovative production.*

***Key words***: *government support, innovation, agricultural production, financing mechanisms, Cobb-Douglas production function, modeling*

## INTRODUCTION

The current macroeconomic instability, the sanctions policy actualize the issues of reducing import dependence in the agro-industrial complex. Under these conditions, the possibility of increasing the volume of funding for agricultural science to stimulate innovative agricultural production, ensuring food security and independence of countries is limited. The strategic priority of achieving a new quality of scientific, technological and economic development is to increase the efficiency of scientific research. Successful world experience shows that the contribution of scientific achievements to the growth of gross domestic product can reach 50% [12]. Of particular importance is the search for an effective model for financing the costs associated with research and development work. The purpose of the state program «Scientific and technological development of the Russian Federation» is the renewal of scientific, technical and innovative activities. According to forecasts, is expected that by 2030 an effective system of reproduction, attraction and development of intellectual potential will be formed, subject to a significant increase in budgetary and extrabudgetary funds for research and development, the creation of an advanced infrastructure for fundamental and applied research [16].

In modern conditions, insufficient investment activity significantly limits the technological development of agro-industrial enterprises, which is confirmed by the relevant statistics: of the total number of completed, accepted and recommended for implementation of scientific and technical developments, about

4% are used; technological innovations are introduced by less than 10% of enterprises. For the possibility of growth of economic indicators in the amount of 4-5% per year, it is necessary to increase the rate of accumulation of fixed capital by 25-27%. Of particular importance in the present period is the determination of priorities for fundamental and applied research, the organization of the introduction of scientific and technical products in agricultural production, and the increase in innovation and investment activity [31].

The effectiveness of investments in agricultural science in the process of innovative structural transformations [6, 29] largely depends on the stability of ties between science, government and business [8,10]. The study of this topic has been widely reflected in foreign and domestic publications. In particular, G. P Pisano [1, 15. 17, 18]. considered the problem of optimizing financial flows in the context of individual sectors of the economy. L. Lambertini, A. Palestini [11,14], presented recommendations for improving the efficiency of investments, highlighting the investment attractiveness of the regions as the most important factor. J.Zhang, Q. Xiao [35] developed specific recommendations for improving the management of investment activity. One of the most important factors in the growth of the competitiveness of the agro-industrial complex is knowledge and scientific and intellectual capital [32]. Among Russian scientists, the most significant are the works of I. G. Ushachev, A.V. Kolesnikova, V.S. Chekalin in the direction of research on budget financing of agricultural science. According to these scientists, in order to solve the problem of insufficient funding for agricultural science and the imperfection of tools to stimulate innovation, it is necessary to increase domestic spending on research in agriculture by 5–7 times. [30]. Despite the fairly broad reflection in the works of domestic and foreign scientists-economists of the problems of financing research activities in various sectors of the economy, there is a need for more in-depth studies of the impact of investment in agricultural science on the technological development of agricultural systems.

## MATERIALS AND METHODS

The purpose of the study is to evaluate the effectiveness of financing agricultural science and develop a mechanism for stimulating innovative agricultural production. The methodological basis of the study was legal documents, research by foreign and Russian scientists on improving the efficiency of research funding in order to implement innovative structural transformations of the agricultural sector; monographic, abstract-logical, analytical, economic-statistical and expert methods.

Based on the compilation of theoretical and methodological approaches of Russian and foreign authors, the author's paradigm for assessing the scientific support of the agricultural sector is proposed using the conceptual provisions of the theory of innovation diffusion and knowledge absorption.

The hypothesis of the study is the assumption that the multiplicative efficiency of financing agricultural science is achieved under the condition of higher growth rates of agricultural production compared to the growth rates of investments in fixed capital of agriculture.

The hypothesis put forward was confirmed empirically: calculations were made to determine the optimal level of funding for agricultural science in order to reduce inter-regional differentiation of innovative development of agricultural production using the methodological tools of the Cobb-Douglas function.

To confirm this hypothesis, the model was linearized by taking a logarithm; based on the results of regression calculations, the parameters of the Cobb-Douglas production function were identified. These parameters make it possible to assess the mutual influence of the volume of costs for scientific research and agricultural production.

The information base for the analysis was the statistical data of Rosstat, the Higher School of Economics, the Ministry of Agriculture on

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innovation, research activities in agriculture, the financing of agricultural science; expert research materials.

## RESULTS AND DISCUSSIONS

With a high scientific potential, agriculture is now showing growth and is the engine of economic growth in the economy as a whole, creating the necessary jobs and gross value added. However, in Russia there is an insufficiently stable trend of inflow of investments into agriculture. Agricultural organizations are characterized by rather low involvement in innovation processes: the development of the latest scientific and technical products was carried out by only 3.1% of organizations; for comparison, in industry, the proportion of organizations implementing technological innovations is 3 times more than in agriculture. It can be assumed that this disproportion reflects the lack of practical application of the results of innovative activities in practice, the imperfection of organizational and financial mechanisms for financing agricultural science in order to stimulate the introduction of domestic innovative products and technologies in agricultural production.

The state of development of agricultural science is assessed by numerous indicators, the main of which for the purposes of the study were chosen: internal costs for research and development, including per researcher and as a percentage of gross domestic product; the number of researchers in total and per 10,000 employees; number of organizations performing research and development.

According to departmental statistics, in 2020, 206 million rubles were allocated from the federal budget. for the performance of scientific research by organizations subordinate to the Ministry of Agriculture of Russia. Amount of funding in 2017–2020 remained relatively stable, while the number of R&D topics changed markedly (Figure 1).

In the subject of agricultural sciences, research in the field of agronomy prevails (about 60%); livestock accounts for a little over 40%.

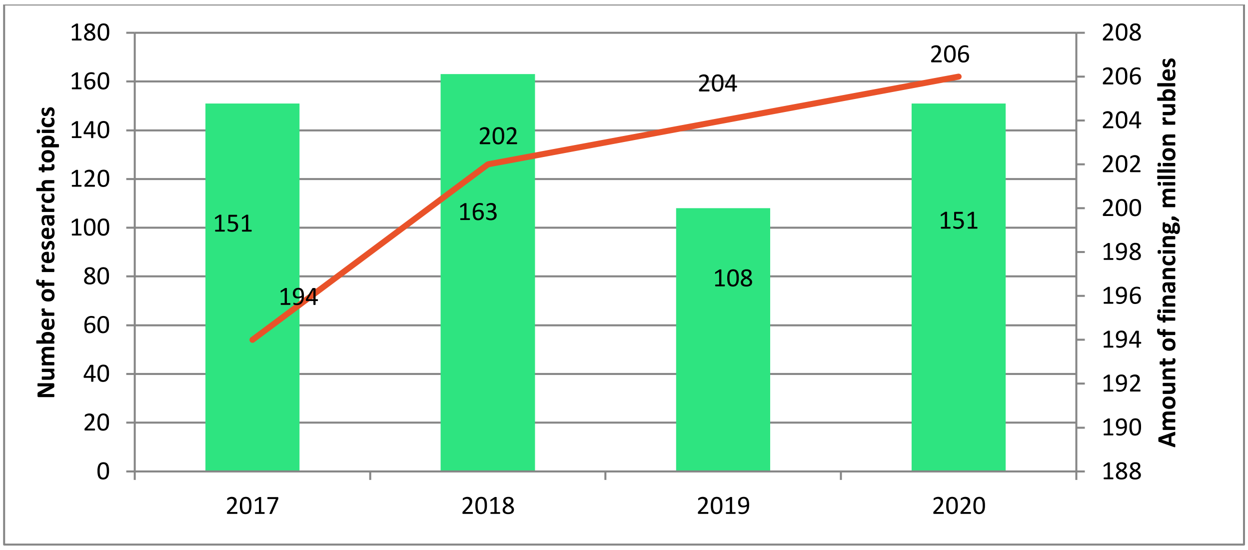


Fig. 1. Dynamics of financing of scientific activities of institutions that are in the department of the Ministry of Agriculture of Russia.
Source: Own calculations based on data [22].

The active use of elements of the precision farming system (parallel driving, informatization and monitoring, yield mapping, differentiated fertilization) allows agricultural organizations and peasant (farm) farms to create electronic field maps. It has been scientifically proven and confirmed in practice that the use of parallel driving systems increases the productivity of material and technical resources, reduces the environmental burden on the soil, and also reduces the cost of such production resources as fuel, seeds, fertilizers, chemical plant protection products [19, 20].

Along with minimizing production costs and reducing the anthropogenic impact on the environment, the advantages of precision farming also lie in the use of new forms of production process control based on digitalization. Currently, automated production systems are widely used in large-scale production of livestock products, mainly in agricultural holdings. The introduction of modern technologies for breeding and rearing a limited number of animal breeds and poultry crosses that are in demand on the market makes it possible to achieve a reduction in resource intensity and an increase in feed conversion. The state of development of agricultural science is assessed by numerous indicators, the main of which for the purposes of the study were chosen: internal costs for research and development, including per researcher and as a percentage of gross domestic product; the number of researchers in total and per 10,000 employees; number of organizations performing research and development.

According to statistics, the share of domestic expenditure on research and development for the development of agriculture in the total volume of domestic expenditure on research and development in 2010-2019. ranged from 2.1% to 2.9%. The number of Russian organizations performing research and development has increased from 3,492 units. in 2010 to 4,175 units. in 2020 or (by 19.6%), while the number of staff engaged in research and development decreased in 2010–2020. from 73,650 people up to 67,933 people (by 7.8%); the rate of decline in the number of researchers in the period under review was somewhat lower (93.9%).

A study of the state of financial, scientific and personnel support shows Russia's significant lag behind a number of foreign countries. Thus, the ratio of domestic research and development costs to gross domestic product in 2019 was 1.03% in Russia; in Belgium - 2.68%; Germany - 3.13%; Sweden - 3.32%; Israel - 4.94%. The target parameters of the national project "Science" suggest bringing spending on Russian science to 1.2% of GDP by 2024, which will ensure only 0.15% economic growth without significant innovative transformation of most of its sectors [27].

The indicator of the number of personnel engaged in research and development per 10,000 people employed in the Russian economy (106 people in 2019) shows a lag behind advanced countries. For example, in Austria this figure was 198 people, in the UK 159, in France 174, in Germany 180 [28].

Table 1 shows the dynamics of the number of patent applications for inventions in various countries.

Table 1. Number of patent applications for inventions filed by residents at home and abroad in 2016-2019

| Countries | Number of applications per 1 million people labor force, units | | | |
|---|---|---|---|---|
| | 2016 | 2017 | 2018 | 2019 |
| Russia | 420.2 | 370.3 | 410.3 | 401.0 |
| Great Britain | 1,565.1 | 1,582.4 | 1,637.8 | 1,585.9 |
| Germany | 4,115.1 | 4,075.1 | 4,134.3 | 4,088.9 |
| USA | 3,211.8 | 3,198.8 | 3,113.4 | 3,141.5 |
| Japan | 6,829.4 | 6,847.7 | 6,734.7 | 6,635.4 |

Source: Own calculations based on data [24].

Insufficient patent activity is also confirmed by the «number of triadic «patent families» indicator, which reflects the number of patent applications filed simultaneously with the patent offices of the EU, the US and Japan. In 2010–2019 its value was in the range from 88 to 111 units, in the UK - from 1,658 to 1,825 units; in Germany - from 4,595 to 5,058 units; in the USA - from 12,743 to 14,818 units; in Japan from 17,489 to 19,295 units. The unsatisfactory state of the scientific and intellectual potential also predetermines Russia's significant lag in a number of indicators of innovative development. For example, the level of innovative activity of Russian organizations is 7–8 than Canada, USA and Switzerland.

The proposed scientific hypothesis assumes the achievement of a multiplicative efficiency of investments in agricultural science, subject to higher growth rates of agricultural production in comparison with the growth rates of investments in fixed capital of agriculture. The calculations performed using the methodological tools of the Cobb-Douglas function confirmed the correctness of this hypothesis.

In domestic and foreign practice, the production function is widely used as a methodological tool for studying static and dynamic processes. [13, 21]. So, M. Cheng, Y. Han developed an economic growth model for the Chinese economy using a modified production function[3, 25]. Gross domestic product was interpreted as a dependent variable, and investment in fixed capital, the number of employees, and energy consumption were taken as independent variables. G.Bella, D.Liuzzi, P.Mattana used the production function apparatus to study the problem of achieving environmental sustainability at the macro level [2].

V.N. Yusim, V.S.Filippov investigated the options for using the Cobb-Dugas production function in order to build predictive models for the development of the national economy. [34].

I.B. Voskoboynikov and V.A. Bessonov substantiated the use of the modified Cobb-Douglas function to assess the dynamics of the physical volume of investments both by industry and the economy as a whole [33].

N.V. Suvorov, R. R. Akhunov, R. V. Gubarev modified the Cobb-Douglas production function to determine its dynamic parameters in the study of the development of industry in the Republic of Bashkortostan [26].

Cheremukhin, D.V. Proskura used the tools of production functions for the information array of agricultural organizations of the Nizhny Novgorod region in order to identify the impact of economic resources on the production of rapeseed, potatoes, cattle and pig meat [4].

The production function characterizes the relationship between the volume of output and factors of production. Most often in macroeconomic calculations, the two-factor Cobb-Douglas function is used, represented by the formula:

$Y = AK^{\alpha}L^{\beta}$, ...........................(1)

where:
Y is the volume of output;
K and L - factors of labor and capital quantified accordingly;
A is a constant in the regression equation, which reflects the influence of hidden factors not included in the calculations and acts as an indicator of production efficiency;
α and β are parameters varying from 0 to 1 ($0 <= \alpha <= 1$, $0 <= \beta <= 1$); they characterize the elasticity of output with respect to labor and capital resources as the ratio of the marginal productivity of the corresponding resource to the average return of each unit of the resource. As a rule, the elasticity of output for each resource is a constant value.

When developing the production function model (1), new parameters were installed in the equation. For the resulting variable, the volume of agricultural output is chosen. Y - Gross agricultural output, 2019, million rubles.

The following indicators were taken as independent variables:
K - Investments in fixed assets aimed at the development of agriculture, 2019, million rubles
L is the average annual number of researchers in the field of agricultural sciences, people, 2019;
A - A constant that takes into account the influence of technical progress and other factors not explicitly represented in the model.

As an information array, data on regions - subjects of the Russian Federation were used. From the number of subjects participating in the statistical analysis, regions were excluded for which there were no separate data on indicators of investment or the number of researchers.

With the use of SPSS software products, regression models of the Cobb-Douglas production function were built and dependencies were selected that adequately approximate the empirical material.

The scientific hypothesis was tested by linearizing the model by taking the logarithm:

$$\ln(Y) = \ln(A) + \alpha*\ln(K) + \beta*\ln(L) \quad ........(2)$$

The above formula reflects a multiple linear regression model. The variables ln(K) and ln(L) are natural logarithms of the values of the above indicators for the constituent entities of the Russian Federation.

According to the results of calculations, a model of the following type was obtained:

$$Y = 532*K^{0.45}*L^{0.23.} \quad ................................(3)$$

The regression analysis parameters are presented in Table 2.

Table 2. Results of applying the regression analysis

| Model | Unstandardized Coefficients | | Standardized coefficients | T | Significance |
|---|---|---|---|---|---|
| | b | Standard error | β | | |
| (Constant) | 6.276 | 0.413 | | 15.211 | 0.000 |
| K | 0.454 | 0.051 | 0.680 | 8.922 | 0.000 |
| L | 0.231 | 0.072 | 0.244 | 3.200 | 0.002 |

Source: Own calculations.

Determination coefficient $R^2$ (0.64), shows a fairly high accuracy of the selection of the regression equation and allows us to estimate the dependence of gross agricultural output on investments and the number of researchers. Calculations showed that an increase in the indicators "Investments in fixed capital aimed at the development of agriculture" and "Number of researchers in the field of agricultural sciences in the constituent entities of the Russian Federation, people" by 1% leads to an increase in the indicator "Gross agricultural output" by 0.45, respectively. % and 0.23%. Thus, an increase in investment by 1% and an increase in the number of researchers by 1% is accompanied by a slower growth in gross agricultural output, which indicates a low efficiency of investments in science [7]. The currently used forms, methods and tools of state support do not sufficiently stimulate domestic agricultural producers to use the achievements of science and technology more widely, there is no differentiated mechanism for distributing budgetary funds between organizations depending on their ability to innovate.

According to Decree of the Government of the Russian Federation of November 30, 2019 No. 1573 “On Amendments to the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials and Food Markets” [5] and the development of Rules for the provision and distribution of subsidies from the federal budget to the budgets of the constituent entities of the Russian Federation to support agricultural production for certain sub-sectors of livestock and crop production are allocated compensatory and incentive subsidies, the level of which is determined according to established methods and calculations [23].

Subsidies to support new production methods are essential for sustainable agricultural development. However, at present, subsidizing is carried out without taking into account the level of innovativeness of agricultural products. It is proposed to allocate subsidies to agricultural producers, taking into account the level of innovation of manufactured products or products produced using innovative methods and technologies. However, this indicator does not take into account the level of innovation in the allocation of subsidies, depending on changes in agricultural production. Meanwhile, subsidies to support new production methods are essential for sustainable development [9].

## CONCLUSIONS

In modern conditions, the task of increasing the production of agricultural products and increasing the competitiveness of products is being updated. It is necessary to improve methodological approaches to the optimal distribution of financial resources to stimulate the introduction of scientific achievements into production. The problem of insufficient investment activity, which significantly limits the technological development of agro-industrial enterprises, involves the development of methods and tools for the optimal distribution of limited budgetary funds to finance scientific research. The results of the calculations show that in the regional context, the financing of scientific research does not affect the volume of production and the level of innovative development of agriculture. Approaches have been developed to optimize the means of financing agricultural science on the basis of the achieved criterion of innovativeness of production. The practical significance of the results of this work lies in the improvement of tools for stimulating innovative production.

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# REVIEW ON THE TOOLS USED IN THE LIFE CYCLE COST ANALYSIS

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***Abstract***

*Life cycle cost analysis (LCCA) is part of the life cycle evaluation methods, highlighting the overall economic cost of a specific product, service or system. The life cycle costs are the sum of the direct, indirect, recurring, nonrecurring and other related costs incurred or estimated to be incurred during the useful life span. This method can be a powerful technique enabling to make the most cost-effective decisions at different life cycle stages. An integrated life cycle evaluation study could combine more methods: Life cycle assessment (ISO 14040:2006), Life cycle cost analysis and social Life cycle assessment. So far, several specific instruments had been developed, IT tools and methods for LCCA method, alone or combined with LCA or other methods. The objective of this study was to present a review of the software instruments used in the Life cycle cost analysis. The LCCA method can be used in particular to model different scenarios. It allows the simulation of several analysis alternatives by resizing the volume of costs from key points.*

***Key words*: *LCCA, life span, cost-effective decisions***

## INTRODUCTION

In this paper, we need to start by presenting what an LCCA analysis is and what it is used for. Also, we find it important to present the fields in which the use of this method began and the areas in which it has expanded until now. LCCA is an analysis technique used to assess the overall long-term economic efficiency between functionally equivalent competing products or processes. So, LCCA is a decision support tool. Being based on well-founded economic principles, the method identifies the strategy that will bring you the best value and which at the same time offers the expected performance at the lowest cost, over the entire analysis period. Regarding the existence of softwares for LCCA calculation, they are found depending on the field in which they are used. Thus, among the many existing dedicated platforms for the industrial field, we only mention here some of these: • RealCost of FHWA • StreetPave and WinPAS from ACPA • CANPave from CAC • Asphalt Pavement Alliance (APA) LCCA Original and LCCA Express etc. More elements regarding the availability and diversity of support platforms for the LCCA method can be found in the Results section. Meanwhile, the LCCA analysis can be performed at different levels of complexity. Its scope can vary from a study on a narrow area of the target process to a detailed analysis with thoroughly researched input data, with additional measures of economic evaluation and assessment of the degree of uncertainty, based on extensive documentation. It is recommended that the scope of the effort be adapted to the needs of the project. Thus, LCCA will provide a significantly better assessment of the long-term cost effectiveness of a project than alternative economic methods that focus only on initial costs or short-term operating costs. LCCA can be applied to capital investment decisions, where relatively higher initial costs are traded for lower future cost obligations. Because LCCA analysis is a method of evaluating the total cost of ownership of the facility, it considers all the costs of acquiring, owning and disposing of a product or service, becoming particularly useful when design alternatives that meet the same performance requirements, but differ in initial costs and operating costs, must be compared to select the one that maximizes net savings. The lowest life cycle cost (LCC) is the simplest and easiest to interpret economic evaluation measure. Other commonly used measures are net benefit, savings-to-investment ratio (or benefit-to-cost savings ratio), internal rate of return, and payback period. They are consistent with the lowest life cycle cost of assessment if they use the same parameters and the same length of study period. Life cycle cost (LCC) analysis can be applied to determine the cost of ownership of a technology (as long as this technology remains in the analyzed location). Meanwhile, in many cases the necessary information is not available or it is unknown and thus it is need to compare or making estimations. On the other hand, it is necessary to underline the cost of not doing the proper process. Not very well managed technologies consume wasted resources, especially economic resources that can well be used for other requirements [28]. An LCCA can be performed in either constant dollars or current dollars, both methods of calculation producing identical present-value life-cycle costs. Still, a constant-dollar analysis does not include the general rate of inflation, while a current-dollar analysis does include it [17]. “Analyzed two methods in a paper: the techno-economic analysis (TEA) and the life cycle cost analysis (LCCA) stated that there are the most widely used approaches for modelling and calculating processes’ economic impacts. A simulation-based TEA is a cost-benefit analysis that simultaneously considers technical and economic factors” [2]. On the other hand, there are authors stating that, “with respect to technological innovation, two diffused methods are the techno-economic assessment (TEA) and the life-cycle costing analysis (LCCA). However, despite their diffusion and approval, these instruments still lack clear guidelines and a complete documentation of their distinctive elements. Furthermore, no discussion exists about their complementarity and integrability, despite the fact that these methods are frequently concurrently used in the analyses” [14]. There are other texts that stated of a common European approach to this method, “It therefore appears appropriate to continue on that path, leaving it to sector-specific legislation to set mandatory objectives and targets in function of the particular policies and conditions prevailing in the relevant sector and to promote the development and use of European approaches to life-cycle costing as a further underpinning for the use of public procurement in support of sustainable growth” [9]. Regarding the methodology approached, we must mention the official European regulations. This refers to the fact that when we apply the cost-benefit method, as part of the LCCA analysis, we should consider the stage of identifying alternative scenarios "All relevant alternatives for the reference scenario are considered. Scenarios that are not feasible for technical, financial, national regulatory reasons or due to time constraints can be excluded at an early stage of the cost-benefit analysis” [20].

## MATERIALS AND METHODS

Life Cycle Cost Analysis (LCCA) is an indispensable technique that uses well-established principles of economic analysis to evaluate the long-term performance of several competing investment options. The LCCA value is obtained by summing up the discounted monetary values of all the benefits and costs that are expected to be incurred for each option. The investment option that brings maximum profits to society is considered the optimal solution. The purpose of an LCCA is to estimate the overall costs of design alternatives and select the design that ensures the system under study will provide the lowest total cost of ownership consistent with its quality and function. LCCA should be performed early in the design process while there is still a chance to refine the design to ensure a reduction in life cycle costs (LCC). The first and most difficult task of an LCCA or any economic evaluation method is to determine the economic effects of alternative projects and to quantify these effects and express them in amounts of money. The steps used in the LCCA methodology can be different as number and structure, from one analyzed system to another, but they are mandatory aspects to follow: establish alternative design strategies, determine activity timing, estimate agency costs, estimate user costs and finally, determine life-cycle cost. Also, the analytical framework of LCCA represents a support system for choosing the input parameters and interpreting the results, which often have a rather high degree of uncertainty, such as the discount rate, used to transform the costs from the different periods, in a common time frame. In order to use the LCCA method in a relevant manner, an understanding of the process is needed both at the theoretical and economic level. The LCCA method compares the alternatives for the life-cycle cost calculation, based on some indicators, for making the best decisions. This requires that the alternatives considered be compared using a common measure of economic value, thus determining the strategies that can be applied. There are several indicators used in defining the alternatives.

For the calculation and interpretation of these indicators, as analysis tools, it has been observed that most modern calculation programs include standard functions for calculating the present value and the annual value (i.e. NPV and EUAC). At the same time, because the different components of the LCCA indicate different things about the alternatives under consideration, these components are usually viewed separately to aid interpretation and evaluation. When two alternatives have very similar net present values over the analysis period, it is advisable to choose the less risky alternative (i.e. the one with the higher proportion of net present value attributable to initial costs), thus LCCA becomes a strategic decision support tool. Following the evaluation of the production process, the economic indicators should be calculated. They will be summing up the monetary values of all revenues and costs evaluated at the time of their production, throughout the entire reference period. Therefore, these amounts will have to be converted into a common time dimension. For this purpose, several alternative methods will be used, among which we will mention the most common.

These are:

Net Present Value:

$$(NPV = \sum_{t=0}^{T} \frac{R_t - C_t}{(1+d)^t}) \quad \text{.....................(1)}$$

Cost-Benefit Ratio:

$$(B/C: \frac{PVR}{PVC} = \sum_{t=0}^{T} \frac{\frac{R_t}{(1+d)^t}}{\frac{C_t}{(1+d)^t}}) \quad \text{.....................(2)}$$

Equivalent Uniform Annual Costs (EUAC) and Internal Rate of Returns (IRR).

The choice of one or another method depends on the level and context in which the analysis is carried out and also on the degree of uncertainty of some parameters. For example, if it is found a high degree of uncertainty of the discount rate within the analyzed area, then it is preferable to use the IRR indicator. The formula of Internal Rate of Return is:

$$IRR = \sum_{t=0}^{T} \frac{R_t - C_t}{(1+IRR)^t} = 0 \quad \text{............(3)}$$

Another alternative is when the analysis period of the process is not known precisely or it is estimated that the period is indefinite. In this case, the EUAC indicator will be used, because it works with the assumption that the process will have an indefinite duration. The formula is the following:

$$EUAC = NPV * \left[\frac{\boldsymbol{d(1+d)^t}}{\boldsymbol{(1+d)^t - 1}}\right] \quad \text{................(4)}$$

where:

*NPV = Net present Value of future costs and benefits,*
*IRR = Internal Rate of Returns,*
*B/C = Benefit/Cost,*
*PVB = Present value of future benefits,*
*PVC = Present value of future costs,*
*d = discount rate,*
*t = time (year),*
*T = life time of the project/process (or analysis period, years),*
*$R_t$ = Revenues to be gain at time t,*
*$C_t$ = costs to be incurred at the time $t$.*

Having these considerations, the choice of an economic indicator or another should answer several questions, including the level of

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benefits and the decision-making analysis involved, the requirements of the initial investments and the future costs etc. [23]. There are numerous costs associated with purchasing, operating, maintaining and disposing of a product or process system, with costs typically falling into the following categories: • initial costs (acquisition costs, construction costs etc.), • fuel costs, • operating, maintenance and repair costs, • replacement costs, • residual values—resale or disposal costs, • financing expenses—interest payments on loans, • non-monetary benefits or costs etc. [12]. Only those costs within each category that are relevant to the decision and significant in amount are necessary to make a valid investment decision. Costs are relevant when they are different for one alternative compared to another and are considered significant when they are large enough to make a credible difference in the LCC of a project alternative. At the same time, the identification and evaluation of those costs that appear during the entire process, represents an important stage in the LCCA analysis. In the figure below (Fig. 1), we have represented a schematization of this typology of costs, namely production costs, processing costs, packaging and labelling costs, retailing costs and transport costs.

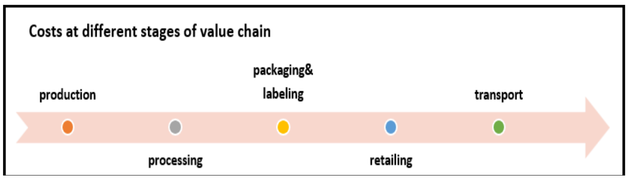


Fig. 1. Costs at different stages of value chain
Source: Own conception.

At this moment it is necessary to mention the fact that in the LCC analysis, an important stage is establishing the size of the analyzed system, called the system boundaries. This will determine the stage in the value chain up to which the costs will be considered. These limits can be set at the level of the production stage or at the level of the packaging and labelling stage etc., which will cause some LCCA analyses to include some longer stages and processes, and others, shorter. That is why it is very important to establish from the beginning the size of the system to which the analysis refers. It should also be mentioned here that the identification of hot points will be done on this system boundaries. Boundaries could be in temporal, spatial, functional and methodological dimensions. In other words, this is the identification of hot points where cost reduction can be considered for the optimization of the production options. These steps apply in any LCCA analysis. In the agricultural system, this analysis has its peculiarities, in the sense that the points are identified according to the stages of the production cycle and the type of production. In Table 1 it is listed an example of life cycle stages and system boundaries, for an apple orchard. We thus identified three big stages and substages): (A) Agricultural production stage costs, (B) Post-harvest stage costs and (C) Transport costs.

Table 1. LCCA steps on Apple supply chain with the Life cycle stages and system boundaries

| (A) Agricultural production stage costs (APC) |
|---|
| **(I) Apple farm establishment (AFE)** |
| **(1) Capital costs at apple farm establishment (AFE investment):** land preparation, planting, anti-hail support system and net |
| **(2) Operational costs at apple farm establishment (AFE operational)**: clearing (deforestation) – process, land preparation, planting, anti-hail support system and net, irigation system, drilling, water reservoir, irrigation |
| AFE TOTAL cost = AFE investment costs + AFE operational costs |
| **(II) I-III years Orchard maintenance (Field operation cost without harvesting) (OM.I-III)** |
| **(1) Capital costs in the first 3 years of orchard maintanance (OM. I-III investment)**: prunning, weeds management, fertilization, pest and diseases |
| **(2) Operational costs in the first 3 years of orchard maintanance (OM. I-III operational)**: prunning, weeds management, fertilization, pest and diseases, irrigation |
| OM. I-III TOTAL costs =OM.I-III investment costs + OM.I-III operational costs |
| **(III) IV-XX years Orchard maintenance (Field operation with harvesting) (OM.IV-XX)** |
| **(1) Capital costs (OM.IV-XX investment)**: prunning, weeds management, fertilization, pest and diseases, irrigation |
| **(2) Operational costs (OM.IV-XX operational)**: prunning, weeds management, fertilization, pest and diseases, irrigation, harvesting |
| OM.IV-XX TOTAL costs = OM.IV-XX investment costs + OM.VI-XX operational cost |
| (A) TOTAL costs APC = AFE TOTAL costs + OM. I -III TOTAL costs + OM.IV-XX TOTAL costs |
| **(B) Post-harvest stage costs (PHC)** |
| **(1) Capital costs at post-harvest level (PHC investment)**: storage, packaging |
| **(2) Operational costs at post-harvest level (PHC operational)**: sorting, storage, packaging |
| (B) TOTAL cost PHC = PHC investment costs + PHC operational costs |
| **(C) Transport costs (TC)** |
| **(2) Operational costs at transport cost (TC operational)**: transport from field to warehouse, transport from warehouse to retail |
| ( C ) TOTAL costsTC operational = TC operational costs |

SYSTEM BOUNDARIES OF THE LCCA METHOD

| | | |
|---|---|---|
| **(A) Agricultural production stage (APC) ( I + II + III)** | **APC (I+II+III)** | **Investment costs + Operational costs = TOTAL costs** |
| (I) Apple farm establishment (AFE) | APC I | |
| (II) I-III years Orchard maintenance (without harvesting) (OM.I-III) | APC II | |
| (III) IV-XX years Orchard maintenance (with harvesting) (OM.IV-XX) | APC III | |
| **(B) Post-harvest level (PHC)** | **PHC** | |
| **(C) Transport cost (TC)** | **TC** | |
| **LCC =** | **APC+PHC+TC** | **TOTAL cost/(no. of years*yearly average production)** |

Source: own representation.

Thus, considering Table 1, we can calculate in which of the stages (A), (B) or (C), as well as in the related sub-stages, it can be identified operations or materials for which costs can be reduced.

## RESULTS AND DISCUSSIONS

The results that can be obtained and the benefits that we can record, interpret and use following the application of the LCCA method, will be different, depending on the level of detail of the stages and sub-stages, as well as the system boundaries we are referring to.

Also, the rules of economic calculation must be respected, namely, when we refer to an analysis over a long period of time, we must consider the reference period. In this sense, the costs will have to be adjusted to constant values for the entire time period of use of the process or system, that is to say, they should be evaluated as present value. In specialized literature, it is mentioned that certain additional measures of alternative economic evaluation can also be taken into account, such as: net savings (NS - operational savings less difference in capital investment costs ), savings-to-investment ratio (SIR - ratio of operational savings to difference in capital investment costs), adjusted internal rate of return (AIRR - annual yield from an alternative over the study period, taking into account reinvestment of interim returns at the discount rate), and simple payback (SPB - time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, without taking into account the time value of money) or discounted payback (DPB - time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, taking into account the time value of money).

Therefore, when evaluating the criteria for possible alternatives, the following relationships will be considered: lowest LCC (for determining cost-effectiveness); NS > 0 (for determining cost-effectiveness); SIR > 1 (for ranking projects); AIRR > discount rate (for ranking projects); SPB and DPB < than study period (for screening projects).

At the same time, when interpreting the results (evaluation of alternatives), the degree of uncertainty will also be considered (Uncertainty Assessment).

In the case of long-term projects, performing an LCCA involves a growing likelihood to choose a project that saves money (on the long term).

This long term will involve a certain uncertainty on the costs level and other inputs values which will suppose some differences in final outcomes against the initial ones.

There are techniques for estimating the cost of choosing the "wrong" project alternative. These are sensitivity analysis or breakeven analysis, which are easily performed without requiring additional resources and usually it is part of the LCCA method.

They produce a single-point estimate of how uncertain input data affect the analysis outcome. Sensitivity analysis is useful for: identifying which of uncertain input values has the greatest impact and affects the range on a specific measure of economic evaluation. This could be done for identify critical parameters by testing different alternatives to answer "what if?" question, by changing the value of each input and holding all others constant, and then recalculate the economic measure to be tested [12].

The fields in which the LCCA method is applied are among the most diverse. It is used most of the time together with the LCA (Life cycle assessment) method. In agriculture, these methods appeared relatively recently, being more often used before in industry or in the construction sector, as seen in the methodology section.

As the objective of this article was the inventory of the software that can be used in LCCA analysis, in the following table we have summarized the LCCA applications that currently exist on the market and the fields in which they are used (Table 2).

Table 2. Platforms that offers support for the LCCA method

| | Short description | Link | Usage field | Observations |
|---|---|---|---|---|
| 1 | The software uses reliability information to calculate a product's cost of ownership. The ability to accurately predict life cycle costs is a key concern in consumer as well as commercial sectors | https://3hti.com/products-2/windchill-quality-solutions/windchill-life-cycle-cost/ [29] | PTC Windchill LCC (formerly Relex Life Cycle Cost): offers industry-standard cost breakdown analysis tools; provides a powerful, flexible LCC tool to meet the cost analysis; compare the cost impact of several alternatives side-by-side, calculate sensitivity and net present value (NPV), and forecast costs throughout the **design**, **production**, repair and **disposal** phases | Account for many different types of costs over the lifetime of a product. Calculate costs, including total lifetime cost, overall system costs, and line-item costs. Perform design and development cost analyses to calculate system planning, concept design, and preliminary system design costs. |
| 2 | openLCA offers the largest collection of data sets and database worldwide for LCA software. | https://www.openlca.org/ [22] | openLCA is versatile and able to meet needs of different user groups, be it e.g. **industry**, **consultancy**, **education**, and **research**. It plays in the same league as commercial LCA software, such as SimaPro, GaBi, or Umberto | Very detailed insights into calculation and analysis results; Life Cycle Costing and social assessment smoothly integrated in the life cycle model. User-friendly; user interface in a variety of languages; advanced and efficient repository and collaboration feature. |
| 3 | The CBS may be directly linked to cost predictions produced by the RCMCost or AvSim modules. | https://www.isograph.com/software/availability-workbench/life-cycle-cost/life-cycle-cost-analysis/ [16] | The costs may be integrated with predicted costs in the LCC cost breakdown structure to provide a time-dependent analysis of a system's whole life cycle cost process. | The Life Cycle Cost (LCC) module of Availability Workbench allows users to build a **hierarchical cost breakdown structure** (CBS) through an unlimited number of indenture levels. |
| 4 | RealCost - the products are in Microsoft Excel spreadsheets with additional Visual Basic for Applications code to provide the graphic user interface. | https://www.fhwa.dot.gov/infrastructure/asstmgmt/lccasoft.cfm [27] | This software provides a tool to perform LCCA for **pavement** selection in accordance with FHWA best practice methods. | The version currently in production is Realcost 2.5.The best practices are outlined in the FHWA's "Life-Cycle Cost Analysis Primer," (.pdf). The software methodology is fully documented in the FHWA's "Life-Cycle Cost Analysis Technical Bulletin," (.pdf) |
| 5 | D-LCC (Decision by Life Cycle Cost) makes the LCC analysis easy & comprehensive. It is a key tool for managers, decision-makers, engineers and other staff involved in system acquisition, proposal writing, production and through-life support | https://aldservice.com/D-LCC.html [1] | Life Cycle Cost (LCC) analysis and Total Cost of Ownership evaluation are the basis for decision making for the wide range of **industries** and **equipment**: from IT systems to submarines. LCC analyzes the total ownership costs of various design alternatives and system's components over the projected life cycle of a system. | D-LCC combines the Cost Breakdown Structure (CBS) with Product Breakdown Structure (PBS) and applies the bottom-up calculation incorporating the time-scale (life cycle phases).D-LCC is data compatible with other ALD packages for Reliability, Maintainability and Logistics Analysis such as RAM Commander. |
| 6 | Opus Suite is used by industry leaders worldwide, in all phases of the system life cycle, to simulate, evaluate and understand how key decisions regarding the design of the technical system, its maintenance & support solution will impact costs & performance. | https://www.systecongroup.com/us/knowledge-center/life-cycle-cost-analysis [26] | Opus Suite can be used in LCC Analyses to for example: model and simulate the cost impact of **decisions**, **compare alternative solutions**, identify cost drivers, identify the most cost-effective changes and improvements, evaluate **financial risks** and sensitivity to data uncertainty, budgeting and **forecasting**. | The flexible scenario modelling in Opus Suite means that cost structure, complexity, formulas, KPI:s etc may be fully tailored to the scope and objectives of the analysis. |
| 7 | The program data is based upon real life data collected at facilities around the world for real world results as opposed to theoretical calculations | https://www.camfil.com/en-us/support-and-services/design-and-engineering/life-cycle-costing-software [5] | Camfil introduced filter life-cycle costing software in the early nineties. The latest version, Camfil LCC Green, considers filter efficiency, **filter life**, filter change **labor**, filter cost, **disposal** costs and allows inputs for all of these factors, plus the largest filter expense, energy usage. | The software has a criterion with guidance to input the specific air quality parameters for a geographic area, based upon data from authorities, such as the United States Environmental Protection Agency (EPA). |
| 8 | LCC analysis software is a Decision Support tool for Design of asset / fleet, maintenance concept, ROI analysis of **IIoT systems**, **tender** bids, **planning** overhauls | https://www.bqr.com/products/apmoptimizer/lcc-life-cycle-cost/ [3] | The main features are: Flexible asset behaviour model, Part libraries, Import tree from Excel or BQR CARE, Fast analytic calculations, Detailed help and wizard | LCC is an important asset KPI that combines financial, technical and logistic aspects of the asset. BQR's LCC module allows to easily define all aspects of the asset operation and maintenance, allowing to calculate the expected LCC of complex assets, accounting for **maintenance**, inspections, spare parts, |

| | | | | |
|---|---|---|---|---|
| | | | | **transportation**, failure and down time cost. This is an excellent Strategic Decision Support System for asset design or overhaul. |
| 9 | BridgeLCC - Life-cycle costing software for preliminary bridge design, is a user-friendly software developed by the National Institute of Standards and Technology (NIST) to help **bridge engineers** assess the cost effectiveness of new, alternative **construction materials**. | https://www.nist.gov/services-resources/software/bridgelcc [19] | BridgeLCC is specifically tailored for comparing new and conventional bridge materials - for example, high-performance concrete versus conventional concrete, but works equally well when analyzing alternative conventional materials. The software uses a life-cycle costing methodology based on both ASTM standard E 917 and a cost classification developed at NIST. | Tools for Designing Cost-Effective Building Systems. The Office of Applied Economics develops economic methods and software to aid industry in evaluating the cost effectiveness of new-technology construction materials, "green" building materials, building energy systems, and other construction processes. BridgeLCC 2.0 supports this effort by helping engineers to **evaluate bridge-related design decisions.** |
| 10 | LCC Software<br>Sassda has developed a world-first app for **stainless steel's** ability to ensure far lower overall LCC. | https://sassda.co.za/about-stainless/the-life-cycle-costing-of-stainless-steel/ [25] | Its ability to provide long-term performance with a minimum of downtime and cost associated with maintenance is determined by calculating the material's lifecycle costing (LCC), which is of particular importance to the **stainless-steel industry**. | The technique uses the standard accountancy principle of discounted cash flow, so that total costs incurred during a lifecycle period are reduced to present values. This allows a realistic comparison to be made. |
| 11 | Automate building life cycle cost calculations. Calculate costs from all life cycle stages. Compare and choose the most eco-friendly and cost-efficient design. Submit LCC results to earn certification credits. | https://www.oneclicklca.com/construction/life-cycle-costing-software/ [21] | The cost data is available for all main **construction materials** in the One Click LCA database. The database production process has used various cost databases, including the Neubau Baupreise Kompakt; Statistische Baupreise für Positionen mit Kurzttexten (BKI) (2017) and the Spon’s Architects’ and Builders’ Price Book (AECOM) (2017). | One Click LCA Life Cycle Costing tool is designed in line with EN 16627 and ISO 15686-5 standards. Results are reported based on the mandatory cost categories in the EN standard, including **construction**, **maintenance**, **operation**, and **end-of-life related costs.** |
| 12 | Assess capital costs for **constructions, systems&floor or ceiling materials** and prepare customised capital cost estimates at any stage of a project. | https://www.iesve.com/software/virtual-environment/applications/life-cycle-cost-analysis [15] | Perform Life Cycle Costing at any stage of the design process and easily incorporate costs for the whole life of the **building**. | Undertake Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and more through the partnership with One Click LCA. |
| 13 | Carrier Releases Free Life Cycle Cost Analysis Software to Compare **Chillers from Different Manufacturers.** PLV Pro provides a quick alternative to detailed energy modelling analyses. | https://www.carrier.com/carrier/en/worldwide/news/news-article/carrier-releases-free-life-cycle-cost-analysis-software-to-compare-chillers-from-different-manufacturers.html [6] | PLV Pro calculates custom part-load weighting factors and condenser water temperatures based on site-specific weather profiles, U.S. Department of Energy building occupancy profiles, chiller staging and **system design**. Criteria include geographical location, building type, quantity of chillers, chiller staging method, design temperatures and chiller plant capacity and design. | Carrier has introduced PLV Pro™, a new software tool to provide fast, easy life cycle cost analysis at no charge for water-cooled chillers from different **manufacturers**. Carrier is a part of Carrier Global Corporation (NYSE: CARR), the leading global provider of healthy, safe, sustainable and intelligent building and cold chain solutions. |
| 14 | LCCA and **Value Engineering** is an approach used to assess the total cost of owning a facility or running a project | https://corporatefinanceinstitute.com/resources/knowledge/finance/life-cycle-cost-analysis/ [7] | Rigorous modelling based on LCCA incorporates value engineering so that a project’s cost outline can lower expenditures by a huge margin. The procedures are done through a series of tests on the cost of operation. | Life cycle cost analysis can be used to assess different **infrastructural sectors** such as **rail** and **urban transport**, **airports**, **highways**, and ITS, as well as ports and **industrial infrastructure**. |
| 15 | BSRIA is involved in 6 out of the 10 work packages within the CILECCTA project | https://www.bsria.com/uk/test-research/research/cileccta/ [4] | CILECCTA is a **large-scale integrating collaborative projects** co-financed by the European Commission under the 7th Framework Programme, Cooperation Work Programme. | CILECCTA has 19 participants from 8 EU. The project has started in 2009 and was active for 4 years. The software developed fully LCC analysis, compatible with codified Price Banks (PBs), as well as Life Cycle Inventories (LCIs), across Europe. |
| 16 | Life Cycle Costing<br>GaBi enables to track different cost factors related with a **process or flow throughout the life cycle.** | https://gabi.sphera.com/software/gabi-software/gabi/functionalities/life-cycle-costing/ [13] | The Life Cycle Assessment solution, GaBi Software, offers the globally broadest compilation of high quality and annually updated databases to suit the data needs. It is key in various costs, such as for **raw materials** or **energy**, personnel, **operating machines**, overheads, **packaging** or | All individual GaBi datasets are comparable by using consistent methods and boundaries as well as common background data and models in their construction. GaBi is enable to display expenses across the life cycle. |

| | | | | |
|---|---|---|---|---|
| | | | **transport**. | |
| 17 | The National Institute of Standards and Technology (NIST) developed the Building Life Cycle Cost (BLCC) to provide computational support for the analysis of capital investments in buildings. They include BLCC, the Energy Escalation Rate Calculator and Handbook 135. | https://www.energy.gov/eere/femp/building-life-cycle-cost-programs [10] | BLCC version 5_3_22 contains the following modules: FEMP Analysis, Energy Project, Federal Analysis, Financed Project Office of Management and Budget Analysis, MILCON Analysis, **Energy and Non-Energy** Project, Energy **Conservation Resilience** Investment Program. BLCC calculates comparative economic measures for alternative designs (net savings, savings-to-investment ratio, adjusted internal rate of return and years to payback). | BLCC conducts economic analyses by evaluating the relative cost effectiveness of alternative buildings and building-related systems or components. Typically, BLCC is used to evaluate alternative designs that have higher initial costs but lower operating costs over the project life than the lowest-initial-cost design. |
| 18 | Life Cycle Costing (LCC) - Business **modelling the whole life cycle of products and services**. | https://www.life-cycle-costing.de/ [18] | Life Cycle Costing (LCC) is an accounting approach, which **addresses the cost implications of a service or asset in a broad sense**. Because of this complete life cycle thinking, LCC is referred to as "womb to tomb" or "cradle to grave" approach. | LCC is often performed beforehand in order to estimate the total cost of ownership of several alternative solutions before irreversible decisions have been taken and the venture is progressed to far to be reverted. |
| 19 | This is a User Guide to the Life Cycle Costing Tool for **Green Public Procurement of Computers and Monitors**. | https://ec.europa.eu/environment/gpp/pdf/EC_LCC_computers_guide_final_updated_Mar2019.pdf [11] | The purpose of the tool is to encourage and facilitate the wide application of life cycle costing (LCC) among public authorities in the EU. The tool has been designed to be used during tendering processes. | The guide provides the key aspects to consider when using LCC in public procurement, especially during the preparatory and tendering stages. It introduces briefly the main sections and elements of the LCC tool itself. |
| 20 | The CRAVEzero spreadsheet is a comprehensive tool to perform life-cycle cost analysis for nZEBs. | https://www.cravezero.eu/pboard/Downloads/LCCTool.htm [8] | The data collection is organized following as a base reference the LCC structure introduced by the Standard ISO 15686-5:2017 (**Buildings and constructed assets- Service life planning**, Part 5: Life-cycle costing). The source used to structure the construction costs is the European Code of Measurement, elaborated by the European Committee of the Construction Economists. | The LCC tool is composed by 6 sheets “Project information”, “WLC”, “Construction cost”, “Calc maintenance”, “Results” and “Charts. The first 4 sheets are devoted to receive input values, the last 2 display the results of the calculation. |
| 21 | Life Cycle Costing in SimaPro, by Andreas Ciroth, Juliane Franze, GreenDeltaTC Berlin, August 2009 | https://pre-sustainability.com/files/2020/09/LCCinSimaPro_english.pdf [24] | LCC has a long tradition in **industry**, especially for those products that have a long life time and/or high **maintenance**, use or disposal costs. Life Cycle Costs are a way to demonstrate that more effort for the production “pays off” by reduced use or maintenance costs or disposal costs. | Conducting an LCC study in SimaPro - new assessment method needs to be created, and then populated with damage categories, subcategories, and flows or “substances” that express economic impacts. Then, these economic impacts need to be assigned to processes where they occur. After, LCC can be calculated, and the result be displayed in Sankey diagram and in the other interpretation features that SimaPro offers. |

Source: Own selection.

In Table 2, a number of 21 software that can be applied to use the LCCA method have been listed and presented.

Most of them are used in industry, manufacturing, production, others in consulting, in research or even in the education sector.

The essential elements for identifying the utility and web allocation for each identified software were introduced, as well as a short description. Because of the field specificities, only some of them can be performed in the agriculture sector (i.e. simaPro, Gabi, openLCA).

## CONCLUSIONS

As conclusion for the findings of the paper, we have tried to summarize the uses of the LCCA method, the constrains and errors that could occurred and possible results. The LCCA methodology, although it is more often used in other sectors than in agriculture, it has also demonstrated its effectiveness in evaluating the results of horticulture processes, for example. Such a method can be used successfully in sizing the production processes in an orchard and exploring the options regarding the costs involved in its entire life span, from the establishment of the plantation until its discharge. Also, the design of alternative results over the life cycle of the project should be presented as feasible solutions of the method, together with the level of the detail that the solutions investigated have had. Thus, using the LCCA method in the studies covering the agricultural systems will bring more emphasize, precision and the possibility to make choice among feasible selections. The constant use of this method in system analysis will bring accuracy and the possibility of having a more advantageous process in terms of costs.

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# FORMATION OF PHYTOCENOSIS OF WINTER BARLEY (*HORDEUM VULGARE L.*) DEPENDING ON HYDROTHERMAL CONDITIONS OF THE AUTUMN PERIOD AND AGRICULTURAL TECHNOLOGICAL MEASURES

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***Abstract***

*This article presents the results of research on the formation of phytocenosis of winter barley (Hordeum vulgare L.) depending on the hydrothermal conditions of the autumn period, varietal characteristics and sowing dates in irrigated lands in the South of Ukraine. Based on long-term research on irrigated lands on the growth and development of plants in the autumn growing season and increasing winter hardiness of winter barley varieties, it has been established that irrigation efficiency has significantly increased over the past twenty years due to regional climate change. Moreover, the extended period of autumn vegetation requires a change in the timing of sowing of winter crops on 13-15 days later. Domestic breeders have created new varieties of winter wheat and winter barley with a short period of vernalization, which are less responsive to the reduction of daylight hours, and some of them have increased winter hardiness.On average, in 1998-2001, the shift in the sowing date of winter barley from September 20 to October 15 led to a deterioration of growth processes, and during the last sowing period, tillering did not occur in the autumn. Among the biomorphological indicators of barley plants there is a close correlation between bushiness, ground mass of plants and their height (r = 0.94-0.99). Compared to the period 1971-1990, the sum of average daily air temperatures in 2001-2005 increased by 110°C, in 2006-2010 – by 191°C, in 2011-2015 – by 222°C and in 2016-2020 – 220°C, and the autumn growing season increased by 8, 10, 15 and 13 days, respectively. On the other hand, the amount of precipitation in most cases was less than the long-term average. During the sowing of winter barley on September 20, the varieties of the winter barley Akademichnyi, Deviatyi val and Dostoinyi have time to carry out tillering well in autumn, forming 3.5–5.2 shoots. During the sowing on October 1, their bushiness was 2.3–3.2, and during the sowing on October 20, the plants do not have time to carry out tillering well, they enter the winter in the phase of 2-3 leaves. For high hardening of winter barley plants and accumulation of sugars in bushes at the level of 30.22-38.8%, the best time for sowing of the studied varieties is the beginning of October.*

**Key words:** *formation of phytocenosis, sowing date, bushiness, irrigated lands, winter hardiness, prolongation of the autumn vegetation period*

## INTRODUCTION

The instability of food grain production observed in the steppe zone in recent years is largely due to regional and global climate change [10, 11]. Statistical analysis of long-term indicators of air temperature shows a steady tendency to increase the average annual air temperature with significant fluctuations of indices in some periods from 7.9 ± 2.9 to 10.0 ± 2.5°C and reduce the amount and instability of natural moisture [17]. On the basis of correlation-regression analysis, mathematical models have been created that reproduce the dependence of grain yield on difficult weather conditions of the growing season, the impact of which reaches 60-70% [13].

It should be recognized that temperature is one of the most important uncontrolled limiting factors of the environment. According to the Intergovernmental Panel on Climate Change (IPCC), in the next 100 years the temperature on the planet will rise by 4-6°C [19], winters will be shorter and warmer, springs will be colder, summer will be hotter [3].

Similar phenomena have been observed in the last four decades in the Orenburg region, where the climate has changed towards a significant increase in average annual air temperature from 4.5°C to 6.2°C and a decrease in annual rainfall – from 380 to 320 mm. For winter and early cereals, these changes led to a sharp decrease in crop yields by about 2 times compared to the maximum in the 90s [8, 18]. Such climatic challenges will lead to even greater aridity of the Southern Steppe of Ukraine. Therefore, in this area only irrigation can ensure sustainable production and high yields of crops [23, 24].

The foundations of the productive potential of winter cereals are laid at the initial stage of plant growth [21]. Therefore, special attention in the cultivation of winter barley should be paid to the autumn growing season, where the key issue is to establish the optimal sowing period.

Global climate change affects some abiotic factors (such as temperature and precipitation). Therefore, adapted varieties to a particular region may react negatively to changing climatic conditions, as they cause inconsistencies in plant phenology [4]. At present, many ecological zones are already showing clear signs of agro-climatic deterioration due to increased drought, leading to a reduction in the active growing season, which in some regions is between cold winters and hot summers. The results of research show that there is a risk of increasing the number of adverse years in many climatic zones, which can lead to negative changes in yields and make it difficult to grow crops [9, 22]. Climate change has made adjustments to the rather complex and ambiguous issue of sowing dates for winter barley, which is one of the main factors in the technological process, which significantly affects the passage of production processes and crop formation. It is known that plants of different sowing dates grow and develop differently, acquire different resistance to biotic and abiotic factors, resulting in different grain size and quality of grain yield [25].

The question of the optimal sowing date of winter cereals in the steppe zone of Ukraine has been studied by many researchers, who came to the conclusion that the optimal time should be shifted on 10-15 days later, compared to the recommendations, which were given 15-20 years ago [15, 20]. Due to global climate change, a number of scientists in their publications also propose to postpone the allowable sowing of winter crops to a later date [5, 26]. Scientists also say that the timing of sowing will be significantly affected by extreme weather conditions, during which heat amplitudes will be replaced by heavy rainfall. Therefore, for coordinated climate forecasts on a pan-European scale, scientists from Europe and other continents model the climate based on temperature, precipitation and extreme winds in order to use it effectively [1, 6, 7, 12].

The complexity of this issue lies in its systemicity and randomness, as the optimal time depends on the predecessor, hydrothermal conditions of autumn, soil moisture, varietal characteristics, fertilizer background and plant protection system against diseases and pests, and other factors. In irrigated lands, due to the possibility of regulating the moisture supply at the time of sowing, this issue is not sufficiently studied. In addition, the creations of high-yielding varieties of the new generation of classical and alternative types require field research to determine which of them best meet the changed climatic conditions [2, 16].

Especially important are the timing of sowing of winter crops in the steppe zone during irrigation, which provides optimal conditions for seedlings. However, in this area almost half of their area is sown annually in the late stages, which leads to insufficient development of vegetative mass of plants and liquefaction, resulting in a sharp increase in the risk of death of winter barley plants in winter [26]. During irrigation, winter barley is sown in a moist sowing layer of the soil, so the limiting factor in the emergence of seedlings is the average daily air temperature, which has been rising recently. Thus, the study, which aims to determine the optimal timing of sowing of winter barley under irrigation in the South of Ukraine, is relevant.

## MATERIALS AND METHODS

The aim of the study was to determine the impact of hydrothermal conditions and sowing dates on the duration of autumn vegetation, bushiness and accumulation of sugars in the tillering nodes of different varieties of winter barley on irrigated lands in southern Ukraine. Field experiments were conducted on the Inhulets irrigated area of the Institute of Irrigated Agriculture of NAAS, in accordance with generally accepted guidelines.

During 1998-2001, six terms of sowing winter barley were studied on irrigated lands after harvesting corn for silage: September 20 and 25 and October 1, 5, 10 and 15. Shallow tillage was used, and pre-sowing irrigation was provided for guaranteed germination. Optimal soil moisture was maintained by vegetative irrigations with a rate of 300-450 $m^3$/ha. The nutrition system provided the introduction of $N_{30}$ in pre-sowing cultivation and $N_{60}$ in early spring. The variety of barley Rosava was sown at a rate of 5 million grains per hectare.

Studies that took place during 2015–2018 on irrigated lands after soybean harvest studied varieties of barley Akademichnyi, Deviatyi val and Dostoinyi. Four sowing dates were studied: September 20, October 1, 10, and 20. The main tillage was shallow, to a depth of 10-12 cm. $N_{45}$ was applied to pre-sowing cultivation in early spring. In order to obtain friendly seedlings and favorable moisture supply for the growth and development of winter barley plants in the autumn period in 2015, post-sowing irrigation was carried out at a rate of 450 $m^3$/ha, and in 2017 – pre-sowing (500 $m^3$/ha) and seed-calling (250 $m^3$/ha). The sowing rate was recommended for the Southern Steppe zone of Ukraine and amounted to 4.5 million seeds per hectare. In the selected samples of tillering nods, the sugar content was determined according to Bertrand (State Standard of Ukraine, 26176-91) in the laboratory of analytical research of the Institute of Irrigated Agriculture. Observations of meteorological values were recorded at the Kherson agrometeorological station, located at a distance of 200-400 m from the field experiment.

## RESULTS AND DISCUSSIONS

The results of research show that the development of winter barley significantly depended on the temperature regime of the autumn period, which is closely related to the timing of sowing.

Thus, the average daily air temperature of five days of the first and second sowing dates was 15.4 and 15.7°C, respectively, the third and fourth – 14.0 and 13.0°C, the fifth and sixth – 12.3 and 10.6°C (Table 1).

Table 1. Average daily air temperature and duration of autumn vegetation of winter barley depending on sowing dates (average for 1998–2000)

| Indexes | Sowing period | | | | | |
|---|---|---|---|---|---|---|
| | 20 IX | 25 IX | 1 X | 5 X | 10 X | 15 X |
| Number of days «sowing-seedlings» | 9 | 10 | 11 | 15 | 16 | 18 |
| Number of days «sowing-cessation of vegetation» | 59 | 54 | 49 | 44 | 39 | 34 |
| The average daily air temperature for the first five days after sowing, °C | 15.4 | 15.7 | 14.0 | 13.0 | 12.3 | 10.6 |
| The sum of average daily air temperatures «sowing-cessation of vegetation», °C | 577.1 | 500.9 | 420.4 | 350.4 | 291.6 | 230.1 |

Source: [27].

Under the conditions of sowing on September 20 and October 1, seedlings appeared on the 9th and 11th days, and in the case of sowing on October 5 and 15 – on the 15th and 18th days.

Prior to the cessation of vegetation in autumn, barley plants, depending on the sowing period, grew from 59 to 34 days, during which the sum of average daily air temperatures from «sowing to cessation of vegetation» in autumn decreased by two and a half times – from 577.1 to 230.1°C.

Under such different temperature conditions, the growth processes took place differently (Table 2).

Table 2. Biometric indicators of winter barley plants at the end of autumn vegetation at different sowing dates (average for 1998-2000)

| Indexes | Sowing period | | | | | | ± | V,% |
|---|---|---|---|---|---|---|---|---|
| | 20 IX | 25 IX | 1 X | 5 X | 10 X | 15 X | | |
| Number of plants at the time of cessation of vegetation in autumn, pcs/m$^2$ | 480 | 406 | 380 | 410 | 464 | 437 | 429 ±37 | 8.8 |
| Number of shoots at the time of vegetation termination in autumn, pcs/m$^2$ | 1540 | 1231 | 901 | 833 | 615 | 438 | 926 ±392 | 43.6 |
| General bushiness | 3.2 | 3.1 | 2.5 | 2.1 | 1.4 | 1.0 | 2±1 | 40.3 |
| Aboveground mass of plants, g/m$^2$ | 404.8 | 318.7 | 214.1 | 158.4 | 111.3 | 74.8 | 213.7 ±133.1 | 59.3 |
| Height of plants, cm | 18.2 | 17.5 | 17.1 | 15.7 | 14.6 | 13.6 | 16.1 ±1.9 | 11.1 |

Source: [27].

The largest number of plants per unit area (480 pieces/m$^2$) was found in the case of sowing on September 20, as well as in later periods – October 10 and 15, 464 and 437 pieces/m$^2$, respectively. The latter was due to the better conditions of moisture supply of the soil layer at the time of sowing in the first period, due to pre-sowing irrigation, and in the latter – due to precipitation. At the same time, during the sowing on October 1, due to the loss of moisture of the upper soil layer, the number of plants at the time of vegetation termination was the lowest – 380 pieces/m$^2$. The number of shoots per unit area, as well as bushiness, starting from sowing on September 20 and ending on October 15, decreased from 1,540 to 438 pieces and from 3.2 to 1.0, respectively. The time factor for the tillering process was decisive. There was a direct dependence of shoot formation on the sowing date – the later the seeds were sown, the less the plants were bushed. At the same time, a decrease in the vegetative mass and height of plants in the late sowing period was also established. Thus, in the case of sowing on September 20 the aboveground weight of plants was 404.8 g, on October 5 – 214.1 g and on October 15 – 74.8 g, and the height of plants reached – 18.2, 17.1 and 13.6 cm, respectively.

The number of days of the interphase period «sowing-cessation of vegetation», which in content is a reflection of sowing dates, has a close correlation with the total bushiness, plant height and their ground weight (r = 0.98-0.99) (Table 3).

Table 3. Matrix of paired correlations of conditions caused by sowing dates and development of winter barley plants in autumn

| | Indexes | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 1 | Number of days «sowing-cessation of vegetation» | x | x | x | x | x | x |
| 2 | The average daily air temperature for the first five days after sowing, °C | 0.97 | x | x | x | x | x |
| 3 | The sum of average daily air temperatures «sowing-cessation of vegetation», °C | 0.998 | 0.96 | x | x | x | x |
| 4 | Number of plants at the time of cessation of vegetation in autumn, pcs/m$^2$ | 0.14 | 0.01 | 0.18 | x | x | x |
| 5 | General bushiness | 0.99 | 0.98 | 0.98 | 0.00 | x | x |
| 6 | Aboveground mass of plants, g/m$^2$ | 0.98 | 0.93 | 0.99 | 0.27 | 0.95 | x |
| 7 | Height of plants, cm | 0.99 | 0.97 | 0.98 | 0.01 | 0.99 | 0.94 |

Source: [27].

Given that these indicators directly reflect the winter hardiness of plants, this dependence is evidence of the determining importance of sowing dates for crop development and winter hardiness. Among the biomorphological indicators of barley plants there is a close correlation between bushiness, ground mass of plants and their height (r = 0.94-0.99). According to the results of the definition, the constructed polynomial model of the fourth degree with high accuracy $r^2$ = 0.9947 describes the change in the coefficient of tillering of winter barley over time (Fig. 1).

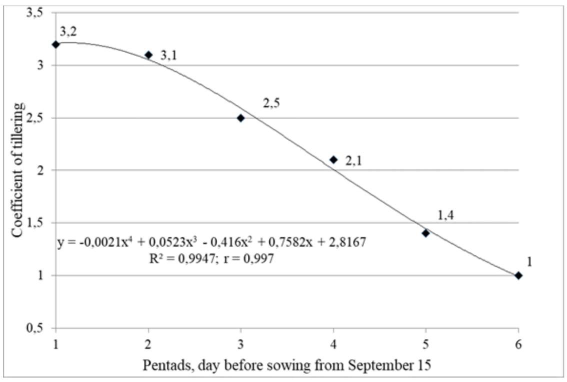


Fig. 1. Polynomial model of change in the value of the coefficient of tillering of winter barley from the time of sowing

Source: [27].

The mathematical model has the form:

$$y = -0.0021X^4+0.0523X^3-0.416X^2+0.7582X + 2.8167$$

where:
y-index is a tillering rate at the appropriate sowing date and x- index– pentodes of days from September 15 to the sowing date of winter barley.

The constructed mathematical models with high accuracy allow to predict the development of winter barley crops by the value of the tillering coefficient. On average, in 1998-2000, the shift in the sowing period of winter barley from September 20 to October 15 led to a deterioration of growth processes, and during the last sowing period tillering did not occur in the autumn. It should also be noted that for 20 years of research, since 2001, there has been a marked change in the temperature regime of the autumn growing season of winter barley. Thus, on average for 1971-1990 during the autumn period the sum of average daily air temperatures was 498°C, and in 2001-2005 it reached 608°C, in 2006-2010 – 689°C, in 2011-2015 – 720°C and in 2016-2020 – 718°C, or on 110, 191, 222 and 220°C more, respectively (Table 4).

Table. 4. Changes in temperature and the duration of the autumn growing season of winter barley by years (data of the Kherson Regional Center for Hydrometeorology)

| Indexes | Value | Years 1971–1990 | 2001–2005 | 2006–2010 | 2011–2015 | 2016–2020 |
|---|---|---|---|---|---|---|
| Sum of average daily temperatures, °C | factual | 498 | 608 | 689 | 720 | 718 |
| | ± | - | +110 | +191 | +222 | +220 |
| Average daily air temperature, °C | factual | 8.1 | 8.6 | 9.6 | +9.9 | +9.5 |
| | ± | - | +0.5 | +1.5 | +1.8 | +1.4 |
| Duration of autumn vegetation, days | factual | 63 | 71 | 73 | 78 | 76 |
| | ± | - | +8 | +10 | +15 | +13 |

Source: [27].

During these periods, the average daily air temperature also increased by 0.5-1.8°C and the duration of autumn plant vegetation by 8-15 days. That is, there have been significant changes in agrometeorological conditions and noticeable in the direction of warming [26]. Research in 2013-2019 also found that in most cases longer and warmer periods of autumn vegetation of winter cereals were observed. Thus, from July to the third decade of September 2014 and 2018 and mid-October of 2015, 2017 and 2019 in the pre-sowing period of winter barley in the south of Ukraine there were very difficult agrometeorological conditions because of air and soil droughts. Due to such weather conditions, soil moisture for barley sowing was critically insufficient. Vegetative watering of soybean crops, as a predecessor, was completed in the first or third decades of August. Therefore, in order to obtain friendly seedlings and favorable moisture for the growth and development of winter barley plants in the autumn, in 2014 pre-sowing irrigation was carried out at a rate of 500 $m^3$/ha, in 2015 – post-sowing (450 $m^3$/ha), and in 2017 – pre-sowing (500 $m^3$/ha) and seed-calling (250 $m^3$/ha). In 2013 and 2016, there was no need for pre-sowing irrigation, as in September there was sufficient rainfall to obtain friendly seedlings – 43.7 and 33.2 mm, respectively.

Pre-sowing and seedling irrigation, which were carried out in 2015 and 2017 and rainfall against the background of high temperatures in November, helped to improve the condition of winter barley plants. During October – November, 62.8 and 52.6 mm of precipitation were received, respectively, which was 98 and 82% of the long-term precipitation rate for this period. In addition, in September and November 2015, and in 2017 in September-October, the high temperature regime was maintained – the average monthly temperature was higher than the long-term norm by 4.5 and 2.9°C and 3.5, respectively, 1.5 and 1.0°C (Table 5).

In autumn 2016, only in September the air temperature was higher by 1.6°C and in October and November – lower by 1.4 and 0.4°C.

Instead, in autumn 2018 and 2019, at the time of winter barley sowing, productive moisture reserves in the seed layer of the soil were 6-8 mm and were insufficient to obtain friendly seedlings, which required September 18 and 17 pre-sowing irrigation at 400 and 500 $m^3$/ha, in accordance. Thanks to watering and

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warm weather, the seedlings appeared on time.

Table 5. Meteorological indicators during the autumn vegetation of winter crops (data from the regional center for hydrometeorology in Kherson)

| Years | Months: September | October | November | Average for the autumn period |
|---|---|---|---|---|
| average daily air temperature, ºC | | | | |
| 2013 | 15.1 | 9.3 | 7.5 | 10.6 |
| 2014 | 18.4 | 9.3 | 3.3 | 10.5 |
| 2015 | 20.9 | 9.4 | 7.3 | 12.5 |
| 2016 | 18.0 | 8.4 | 4.0 | 10.1 |
| 2017 | 19.9 | 11.3 | 5.4 | 12.2 |
| 2018 | 18.7 | 12.5 | 2.7 | 12.5 |
| 2019 | 18.1 | 11.6 | 7.1 | 12.3 |
| **Norm** | **16.4** | **9.8** | **4.4** | **10.2** |
| the amount of precipitation, mm | | | | |
| 2013 | 43.7 | 53.9 | 4.0 | 101.6 |
| 2014 | 43.0 | 34.2 | 21.5 | 98.7 |
| 2015 | 4.6 | 18.6 | 44.2 | 67.4 |
| 2016 | 33.2 | 74.4 | 34.2 | 141.8 |
| 2017 | 0.7 | 12.0 | 40.6 | 53.3 |
| 2018 | 42.8 | 9.6 | 31.1 | 83.5 |
| 2019 | 13.0 | 62.0 | 38.0 | 113.0 |
| **Norm** | **40.0** | **28.0** | **36.0** | **104.0** |

Source: [27].

In general, the calendar autumn of 2019, as in 2018, was held at elevated temperatures, and the average air temperature was 12.3 and 12.5°C, respectively, which is on 2.1 and 2.3°C above the long-term norm. The amount of precipitation in the autumn of 2019 was 113 mm (109% of the seasonal norm), and in 2018 – 84 mm (81% of the seasonal norm). The amount of precipitation received during the period of «sowing-cessation of autumn vegetation» of different calendar terms differed significantly during the research years and ranged from 4.3 to 63.9 mm in 2013, from 27.9 to 87.0 mm – in 2014 from 57.2 to 65.3 mm– in 2015, from 23.7 to 98.0 mm – in 2016, from 93.3 to 96.0 mm – in 2017, from 6.1 to 22.1 mm – in 2018 and from 60.8 to 131.2 mm – in 2019.

Conditions were wet in 2016, when since September 20 and October 1, 10 and 20 until the cessation of vegetation of winter barley plants fell on 42.1 mm, 56.0, 28.9 and 0.7 mm more than the long-term average for 1945–2010. In 2013, 2015, 2017 and 2018, the amount of precipitation at all sowing dates was less than the long-term average. However, if in 2013 the largest shortage of precipitation was observed in the case of sowing on October 20 (-39.7 mm), then in 2015, 2017 and 2018 in the case of sowing on September 20 and October 1 – respectively: 50.7 and 36.7 mm, 36.3 and 23.0 and 31.5 and 30.0 mm.

Precipitation during the autumn vegetation in the case of sowing on September 20 and October 1 in 2019 exceeded the norm by 16.2 and 18.1 mm, respectively, but in the case of sowing on October 10 and 20 was lower than it by 26.2 and 21.2 mm. In 2014, the amount of precipitation in the case of sowing on September 20 and October 10 was higher than the long-term average by 20.2 and 3.2 mm, while in the case of sowing on October 1 and 20 it was lower by 6.8 and 5.9 mm. Thus, in the years of research there was a different supply of precipitation of winter crops in the autumn growing season (Table 6). According to the average long-term values, the cessation of active vegetation of winter grain crops in the Kherson region occurs on November 25. The actual duration of the autumn growing season differed markedly over the years of research.

Table 6. Hydrothermal conditions of the autumn period «sowing-cessation of autumn vegetation» of winter cereals depending on the timing of sowing

| Year of sowing | Sowing period: September 20 | October 1 | October 10 | October 20 | |
|---|---|---|---|---|---|
| the amount of precipitation for the period «sowing-cessation of autumn vegetation», mm | | | | | |
| 2013 | 63.9 | 57.9 | 40.0 | 4.3 | |
| ± from the norm | -9.1 | -1.1 | -9.0 | -39.7 | |
| 2014 | 87.0 | 46.0 | 46.0 | 27.9 | |
| ± from the norm | +20.2 | -6.8 | +3.2 | -5.9 | |
| 2015 | 65.3 | 65.3 | 64.9 | 57.2 | |
| ± from the norm | -50.7 | -36.7 | -27.1 | -25.8 | |
| 2016 | 98.1 | 98.0 | 60.9 | 23.7 | |
| ± from the norm | +42.1 | +56.0 | +28.9 | +0.7 | |
| 2017 | 96.7 | 96.0 | 93.4 | 93.3 | |
| ± from the norm | -36.3 | -23.0 | -15.6 | -6.7 | |
| 2018 | 22.1 | 9.6 | 6.1 | 6.1 | |
| ± from the norm | -31.5 | -30.0 | -23.5 | -14.5 | |
| 2019 | 131.2 | 119.1 | 64.8 | 60.8 | |
| ± from the norm | +16.2 | +18.1 | -26.2 | -21.2 | |
| Avarage | 80.6 | 70.3 | 53.7 | 39.0 | |
| ± from the norm | -7.0 | -13.4 | -9.9 | -16.2 | |
| duration of the period «sowing-cessation of autumn vegetation», days | | | | | cessation of vegetation |
| 2013 | 68 | 58 | 48 | 38 | 27. XI |
| 2014 | 64 | 54 | 44 | 34 | 23. XI |
| 2015 | 100 | 90 | 80 | 70 | 29. XII |
| 2016 | 56 | 46 | 36 | 26 | 15. XI |
| 2017 | 114 | 104 | 94 | 84 | 12. I |
| 2018 | 54 | 44 | 34 | 24 | 13. XI |
| 2019 | 100 | 89 | 78 | 69 | 28. XII |
| average for 2013–2021 | 79 | 69 | 59 | 49 | 8. XII |
| average perennial for 1945–2010 | 66 | 56 | 46 | 36 | 25.XI |

Source: [27].

In 2013 and 2014, the cessation of winter wheat vegetation took place on November 27 and 23, which is close to the long-term average. In 2015 and 2017, there was a long vegetation of winter crops, which ended only on December 29 and January 12, respectively.

This temperature regime led to an extension of the growing season by 30 and 45 days relative to long-term values. The opposite situation was observed in autumn 2016, when winter crops stopped growing on 11 days earlier than long-term values – November 15, and December was on 1.1°C colder than normal. In 2018, the decrease in temperature on November 13 suspended the vegetation of winter crops for a week and a half earlier than usual. Much warmer weather conditions were observed in November and December 2019, so winter wheat plants did not stop their growing season. The maximum air temperature in December reached 11-14°C of heat, while the minimum was 3-7°C of frost.

The average air temperature in December was +4.3°C, which is on 4.2°C above the climatic norm. During 137 years of meteorological observations, such a high average monthly air temperature was observed only in 1886, 1901 and 1960, when the warmest nights were recorded on December 22 and 24 – over +10.8°C and 6.6°C. According to observations, +6.1°C was recorded in December 1960 and +6.3°C in 2014. At the end of the month, there was a gradual decrease in air temperature at night to 0.4-1.8°C of frost, due to why winter crops stopped the growing on December 28, 2019.

Long-term observations in the steppe zone have shown that the duration of autumn vegetation should be 40-50 days to prepare barley for winter conditions. For the normal development of plants from germination to the end of the growing season, 200-300°C of effective temperatures at values of biological zero +5°C are required. This amount of effective temperatures helps plants to form sufficient biomass and the amount of sugars needed for successful overwintering [5, 14].

For sowing in the period from September 20 to October 20, the duration of the autumn growing season in 2013 and 2014 was within close to the optimal values and amounted to 68-34 days. Also close to each other was the duration of autumn vegetation of winter wheat plants in 2016 and 2018, but the shortest duration for all years of research – 56-26 days and 54-24 days, respectively. In 2015 and 2019, at the specified sowing dates, the duration was 100-70 and 100-69 days.

The longest autumn growing season was in 2017, which was 114-84 days. Studies conducted in 2015-2018 with sowing dates show a better autumn development of barley plants than 15 years later.

Thus, for sowing in the period from September 20 to October 1, full seedlings appeared for 9-10 days, for sowing on October 10 and 20 – for 16 and 23 days (Table 7).

Table 7. Duration of autumn vegetation of winter barley and the sum of temperatures for this period depending on the sowing period (average for 2015-2017)

| Sowing period | Duration (days) | | The sum of temperatures for the period, ° C | |
|---|---|---|---|---|
| | sowing – seedlings | sowing – the cessation of autumn vegetation | sowing – seedlings | sowing – the cessation of autumn vegetation |
| September 20 | 10 | 90 | 169 | 741 |
| October 1 | 9 | 80 | 110 | 564 |
| October 10 | 16 | 70 | 156 | 451 |
| October 20 | 23 | 60 | 166 | 325 |

Source: [27].

In the case of sowing on September 20, the vegetation of plants lasted an average of 90 days in autumn, and the sum of average daily temperatures was 741°C, but in the case of sowing on October 20, these figures decreased to 60 days and 325°C, respectively. Significant influence of sowing dates on growth and development of plants in autumn, their bushiness is noted.

During the first sowing period (September 20) the most intensive growth processes and tillering of plants took place, while in the crops of the second (October 1) and the third sowing periods (October 10) they slowed down, and in the last period (October 20) – their inhibition was observed due to average daily air temperature. Varietal peculiarities were also manifested.

In the case of sowing on September 20, winter barley varieties Akademichnyi, Deviatyi val and Dostoinyi created an average of 3.8-4.4 shoots before entering the winter (Fig. 2).

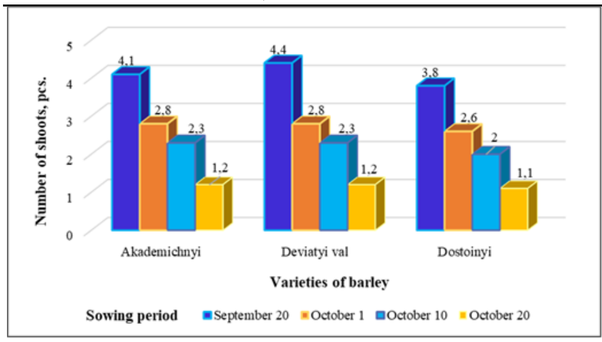


Fig. 2. Bushiness of winter barley varieties at different sowing dates (average for 2015-2017)
Source: [27].

In the case of sowing on October 1 and 10, the bushiness, on average for the years of research, was 2.6-2.8 and 2.0-2.3. At the same time, due to the long autumn vegetation in 2015 and 2017, the plants were at the beginning of the tillering phase on October 20, while they usually did not have time to start it. At the same time, the conditions of these years during the first sowing period led to excessive tillering. Among the varieties, tillering of the variety Deviatyi val was more intensive. The obtained data indicate that the sum of the average daily air temperatures of autumn vegetation for optimal development of winter barley plants should be 450-560°C. The timing of sowing significantly affected the preparation of plants for overwintering. This is very important, because winter barley does not have high winter hardiness and in some years, even in southern Ukraine, its crops are damaged by frost and liquefied, which leads to a significant reduction in yield. During the years of research, winters were favorable for overwintering winter barley, so it was not possible to determine the effect of sowing time and variety on winter hardiness of plants. However, it is known that there is a direct correlation between frost resistance and the content of soluble sugars in the nodes of winter barley tillering [3].

Our research also found that in the nodes of winter barley bushes, the most sugars accumulated during sowing on September 20 and October 1, and the least – on October 20. Thus, for sowing on September 20 and October 1, 2015, at the time of the cessation of autumn vegetation, 30.96-31.68 and 30.22-31.65% of sugars were in the nodes of tillering of plants, in 2016 – 38, 29-38.44 and 36.70-38.8% and in 2017 – 33.30-33.70 and 31.87-32.99%, in the case of sowing on October 20 their number was lower and amounted to 25.67-25.69%, 24.48-25.01 and 24.20-24.31%, respectively (Table 8).

Table 8. Sugar content in tillering nodes of winter barley before plants entrance in winter period and at the end of winter depending on the variety and sowing date

| № | Variety | Sugar content on dry matter before plants entrance in winter period, % | | |
|---|---|---|---|---|
| | | 03.12.2015 | 02.12.2016 | 04.12.2017 |
| | | sowing date September 20 | | |
| 1 | Akademichnyi | 31.68 | 38.29 | 33.70 |
| 2 | Deviatyi val | 30.96 | 38.44 | 33.30 |
| | | sowing date October 1 | | |
| 3 | Akademichnyi | 30.22 | 36.70 | 31.87 |
| 4 | Deviatyi val | 31.65 | 37.85 | 32.99 |
| | | sowing date October 10 | | |
| 5 | Akademichnyi | 29.38 | 32.15 | 28.67 |
| 6 | Deviatyi val | 28.52 | 31.21 | 29.02 |
| | | sowing date October 20 | | |
| 7 | Akademichnyi | 25.67 | 24.48 | 24.20 |
| 8 | Deviatyi val | 25.69 | 25.01 | 24.31 |

Source: [27].

The latter is due to the fact that in the case of sowing on October 20 the plants do not have time to accumulate enough sugars before winter and obtain good hardiness, especially in autumn 2016 and 2017. During this sowing period most sugars were in the variety Deviatyi val. That is, for high hardening of winter barley plants, the best time for sowing of the studied varieties is the beginning of October.

## CONCLUSIONS

In the case of sowing on September 20, the vegetation of plants in autumn lasted an average of 82 days, and the sum of average daily temperatures was 724°C, of sowing on October 1 – 72 days and 540°C, for sowing on October 20 – 52 days and 330°C, respectively. In the case of sowing winter barley on September 20, plants of all varieties had time to carry out tillering well in autumn, had a bushiness of 3.5-5.2, of sowing on October 1 the bushiness was 2.3-3.2, and for sowing on October 20 the plants did not have time for tillering, they entranced in winter in the phase of 2-3 leaves.

For high hardening of winter barley plants, the best sowing period of the studied varieties is the beginning of October, during which

30.22-38.8% of sugars accumulated in the bush nodes of plants during the cessation of autumn vegetation, which is on 5.74-13.11% more than in the case of sowing on October 20.

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# ECONOMIC FEASIBILITY OF APPLICATION OF BACTERIAL AND FUNGAL DRUGS ON SEED-USED ALFALFA

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***Abstract***

*The aim of the work was to study the influence of rhizobacteria, arbuscular-mycorrhizal fungi and their combination on alfalfa seed productivity and the economic effect of their use. The research was conducted during 2018−2020 in a three-factor field experiment under different conditions of moisture (irrigated and non-irrigated) and three varieties of alfalfa under inoculation with bacterial and fungal preparations at the experimental field of the Institute of Irrigated Agriculture of the NAAS, located in the steppe zone of Southern Ukraine. In the first year of the life of the herbaceous plant, the seed yield under irrigation was 187.0 kg/ha, which was 83.5 kg/ha more than under natural irrigation conditions. Alfalfa cultivars also differed in seed yield. The minimum seed yield was obtained on the control variant (without inoculation) with irrigation - 147.9 kg/ha in the Unitro variety, 180.6 kg/ha in the Elehiya variety and 161.8 kg/ha in the Luyiza variety, while without irrigation 79 .9, 106.5 and 89.0 kg/ha, respectively. The highest seed yield was obtained by complex (AMF and Sinorhizobium) seed inoculation with Drugs 2 and 4. In the sum of two years, the lowest seed yield was also obtained by the control option (without inoculation) and amounted to 588.5 kg/ha when irrigated in the Unitro variety , of the Elehiya variety - 695.9 and 631.9 in the Luyiza variety, under natural moisture conditions - 386.5, 463.8 and 417.3 kg/ha, respectively. The highest seed productivity under complex inoculation (Drug 2 and Drug 4), which amounted to 715.7–725.7 kg/ha with irrigation in the Unitro variety, 842.2–864.0 kg/ha in the Elehiya variety and 769.9– 780.5 kg/ha in the Luyiza variety, while under conditions of natural moisture – 451.5–454.1 kg/ha, 534.9–547.2 and 485.4–488.0 kg/ha, respectively. The best indicators of economic efficiency were obtained with irrigation, namely the cost price was 1.30 €/kg, conditional net profit – 1,775.40 €/ha. The highest seed productivity was characterized by the Elehiya variety, which, when irrigated, had a seed cost of 1.19 €/kg, conditional net profit of 2,008.36 €/ha, under conditions of natural moisture 1.21 and 1,297.60, respectively. Among the inoculants, the lowest cost price and the largest conditional net profit were obtained with the use of drug 2, which amounted to 1.30 €/kg and 1,779.09 €/ha for irrigation in the Unitro variety, 1.10 €/kg and 2,288.00 for the Elehiya variety €/ha and 1.21 €/kg and 1,980.88 €/ha in the Luyiza variety. Under conditions of natural moisture, the values of these indicators in alfalfa varieties were: 1.39 and 1,074.06, 1.16 and 1,416.63 and 1.29 €/kg and 1,198.69 €/ha, respectively. Inoculation of seeds with fungal and bacterial drugs contributed to the increase of seed productivity, regardless of the year of life of the grass stand, variety and moisture conditions. However, the highest seed yield, and correspondingly the lowest cost and the highest profit, was obtained by complex (AMF and Sinorhizobium) seed inoculation.*

**Key words:** *alfalfa, variety, seed productivity, natural moisture, drip irrigation, rhizobacteria, arbuscular mycorrhiza, cost, economic effect*

## INTRODUCTION

Among perennial fodder grasses, alfalfa has gained the greatest popularity and distribution in the world. Alfalfa is positioned as a solution to the problem of vegetable protein in animal feed, but the practical value of alfalfa is not limited to its fodder qualities. It also performs other important functions: it enriches the soil with nitrogen, accumulates a large amount of crop residues, root mass, improves the soil structure, reduces the effect of water and wind erosion, and is a good precursor for many agricultural crops [40, 41]. However, the expansion of the sown areas of this valuable fodder crop does not occur due to the lack of sufficient seed material, which in turn is associated with low seed productivity.

Increasing the seed productivity of alfalfa is an extremely important and complex issue that can be solved by creating new varieties, as well as by improving cultivation technology, which directly or indirectly improves the processes of growth and development, the formation of generative organs, and increases the yield of alfalfa seeds [38]. An effective factor affecting the yield of alfalfa seeds is inoculation with bacterial drugs, while the volume of the root mass increases, symbiotic processes are activated, and the resistance of plants to environmental stress factors increases, which is a very important condition for increasing seed productivity [39].

To solve this problem, new approaches to rational nature management with a focus on biologicalization of agriculture are needed. To use cheap biological nitrogen in agricultural production, many countries increase the area sown under leguminous crops, and also widely use pre-sowing treatment of seeds with drugs of nodule bacteria obtained on the basis of active strains of *Rhizobium* [35]. In recent years, there has been considerable interest in rhizobacteria, which provide plants with nutrients for better growth and development and suppress root pathogens [9, 23]. Bacteria bind atmospheric nitrogen, increase its natural supply to the soil due to fixation of atmospheric nitrogen, which reduces production costs by reducing the application of mineral fertilizers and contributes to the preservation of the environment [3, 22, 27]. Therefore, pre-sowing seed inoculation should be a mandatory agro-practice in the technology of growing leguminous crops.

Leguminous plants and nodule bacteria have a significant effect on the viability of each other. For example, alfalfa plants in symbiosis with selectively selected inoculant strains acquire great resistance to stressful conditions, which is expressed in increased plant productivity. Plants assimilate substances that rhizobia synthesize, including for protection against salt stress, at the same time, plant roots produce exudate, which stimulates the growth of bacteria in the rhizosphere [17]. The rhizosphere contains 10–50 times more bacteria and 5–10 times more fungi compared to the soil far from the roots [34]. That is why plant-microbial systems resistant to the influence of abiotic stress factors are in great demand for the development of phytoremediation technologies for the restoration of degraded soils [18, 31, 43].

It is known that in increasing the yield and quality of leguminous crops, including alfalfa, biological drugs based on nodular bacteria *Rhizobium*, which are able to enhance symbiotic nitrogen fixation, as well as suppress plant diseases by inducing resistance to adverse environmental factors and give an increase, play a significant role harvest of green mass [29].

However, in recent years, great interest has been shown in the selection, for seed inoculation, of the most effective combinations of different strains of symbiotic microorganisms, since monospecies systems are not very stable by nature and, under conditions of stress, are vulnerable to competitors, pathogens and other factors that affect their functioning in agrocenoses. The advantages of using consortia over pure ones are multifaceted action, increased resistance and adaptation to environmental fluctuations, and increased efficiency of plant-microbial interaction [21, 25], including phosphate-mobilizing bacteria that mobilize hard-to-reach phosphorus compounds into easily accessible ones for plants [26, 45]. In addition, most types of phosphate-mobilizing bacteria have a beneficial effect on plants, stimulating their growth and photosynthetic processes due to the release of vitamins and phytohormones by microorganisms, their production of antibiotics that inhibit the development of pathogens; transfer of mineral elements into a form accessible to plants [33].

The interaction between microorganisms in the rhizosphere has a profound effect on growth and development, improving nutrition, protecting against biotic and abiotic stresses and increasing plant immunity in agroecosystems and in natural ecosystems [28]. However, most research on rhizospheric microorganisms has focused on bacteria rather than fungi [16]. Among the various microorganisms that colonize the rhizosphere, arbuscular mycorrhizal fungi (AMF) are unique because they reside partly inside the root and partly outside the root, thus influencing other microorganisms in the soil as well as plant growth and development [30, 32, 37]. AMF, forming a symbiotic association with higher plants, contributes to a better assimilation of nutrients such as phosphorus, zinc, copper and others [2, 5, 7, 42], while increasing the yield of agricultural crops. Studies conducted on phosphorus-deficient soils have shown that AMF improve the phosphorus nutrition of plants, and the degree of saving is about 50% of the application of phosphorus fertilizers without a negative impact on the growth, development and yield of agricultural crops [12, 36]. AMF protect plants from biotic and abiotic stresses [15, 19], and also stimulate the production of substances that regulate growth and development, improve photosynthetic processes, osmotic regulation in conditions of drought and salinity, and increase resistance to soil pests and diseases [1].

Synergism of the interaction between AMF and rhizobacteria compared to monoinoculation with either of them was previously reported [6, 8]. AMF and rhizobacteria in the soil and tissues of plant roots jointly interact with each other, which contributes to the improvement of plant growth and development by increasing the availability of nutrients, the penetration of hyphae into the roots of plants, the survival and improvement of the functioning of bacteria, protection from biotic and abiotic stresses [24].

## MATERIALS AND METHODS

The aim of the work was to study the influence of rhizobacteria, arbuscular-mycorrhizal fungi and their combination on alfalfa seed productivity and the economic effect of their use.

Research was conducted during 2018−2020 at the experimental field of the Institute of Irrigated Agriculture of the NAAS. In terms of soil and climate, it is located in the steppe zone of the Ingulets irrigated massif.

The method of establishing a field experiment is split plots. Main plots (factor A) – moisture conditions (irrigated and non-irrigated) sub-plots (factor B) – alfalfa varieties (Unitro, Elehiya and Luyiza); sub-subplots (factor C) – seed treatment with bacterial and fungal drugs: 1 – control (without inoculation); 2 – Drug 1 – *Glomus intraradices* – 132 spores/g. The drug consumption rate is 15 g/kg of seeds; 3 – Drug 2 – *Glomus aggregatum* – 83 spores/g; *Glomus intraradices* – 83 spores/g; *Glomus mosseae* – 83 spores/g; *Glomus etunicatum* – 83 spores/g; *Glomus clarum* – 11 spores/g; *Glomus monosporum* – 11 spores/g; *Paraglomus brazilianum* – 11 spores/g; *Glomus deserticola* – 11 spores/g; *Gigaspora margarita* – 11 spores/g; *Pisolithus tinctorious* – 187,875 spores/g; *Rhizopogon luteolus* – 5,219 spores/g; *Rhizopogon fulvigleba* – 5,219 spores/g; *Rhizopogon villosullus* – 5,219 spores/g; *Rhizopogon amylopogon* – 5,219 spores/g; *Scleroderma citrinum* – 5,219 spores/g; *Scleroderma cepa* – 5,219 spores/g; *Azotobacter chroococcum* – 525,000 colonies/g; *Bacillus subtilis* – 525,000 colonies/g; *Bacillus licheniformis* – 525,000 colonies/g; *Bacillus azotoformans* – 525,000 colonies/g; *Bacillus megaterium* – 525,000 colonies/g; *Bacillus coagulans* – 525,000 colonies/g; *Bacillus pumilus* – 525,000 colonies/g; *Bacillus thuringiensis* – 525,000 colonies/g; *Bacillus amyloliquefaciens* – 525,000 colonies/g; *Paenibacillus durum* – 525,000 colonies/g; *Paenibacillus polymyxa* – 525,000 colonies/g; *Saccharomyces cerevisiae* – 525,000 colonies/g; *Pseudomonas aureofaciens* – 525,000 colonies/g; *Pseudomonas fluorescens* – 525,000 colonies/g; *Trichoderma koningii* – 187,875 colonies/g; *Trichoderma harzianum* – 125,250 colonies/g. The consumption rate of the drug is 25 g/kg of seeds; 4 – Drug 3 – *Glomus aggregatum* – 78 spores/ml; *Glomus intraradices* – 78 spores/ml; *Glomus mosseae* – 78 spores/ml; *Rhizopogon amylopogon* – 116 spores/ml; *Rhizopogon fulvigleba* – 127 spores/ml; *Rhizopogon villosullus* – 118 spores/ml. The consumption rate of the drug is 25 ml/kg of seeds; 5 – Drug 4 – *Glomus aggregatum* – 17 spores/ml; *Glomus* *intraradices* – 17 spores/ml; *Glomus mosseae* – 17 spores/ml; *Glomus etunicatum* – 17 spores/ml; *Azotobacter chroococcum* – 24,960 colonies/ml; *Bacillus subtilis* – 24,960 colonies/ml; *Bacillus licheniformis* – 24,960 colonies/ml; *Bacillus azotoformans* – 249,600 colonies/ml; *Bacillus megaterium* – 24,960 colonies/ml; *Bacillus coagulans* – 24,960 colonies/ml; *Bacillus pumilus* – 24,960 colonies/ml; *Bacillus thuringiensis* – 24,960 colonies/ml; *Bacillus amyloliquefaciens* – 24,960 colonies/ml; *Paenibacillus durum* – 24,960 colonies/ml; *Paenibacillus polymyxa* – 24,960 colonies/ml; *Saccharomyces cerevisiae* – 24,960 colonies/ml; *Pseudomonas aureofaciens* – 24,960 colonies/ml; *Pseudomonas fluorescens* – 24,960 colonies/ml. The consumption rate of the drug is 115 ml/kg of seeds; 6 – Drug 5 – *Sinorhizobium meliloti* – $5\times10^9$ colonies/g, *Rhizobium leguminosarum* – $5\times10^9$ colonies/g. The consumption rate of the drug is 2.57 g/kg of seeds; 7 - Drug 6 is a complex highly effective multifunctional drug based on symbiotic nitrogen-fixing and phosphate-mobilizing bacteria. The consumption rate of the drug is 30 ml/kg of seeds. Sowing period is early spring. Wide-row sowing with a row spacing of 70 cm. The area of the sowing area is 60 m$^2$, the accounting area is 40 m$^2$, repetition 3 times.

Statistical processing of experimental data was carried out using programs AgroSTAT, XLSTAT, Statistica (v. 13).

## RESULTS AND DISCUSSIONS

In the first year of the grass stand's life (2018–2020), the seed yield under irrigation was 187.0 kg/ha, which was 83.5 kg/ha more than under natural irrigation conditions. Alfalfa cultivars also differed in seed yield. Thus, under irrigation, the yield of the Unitro variety was 169.1 kg/ha, of the Elehiya variety - 206.7 and 185.3 kg/ha of the Luyiza variety, while under the conditions of natural moisture - 90.2, 119.9 and 100.5 kg /ha, respectively (Table 1).

Table 1. Seed productivity of alfalfa varieties per cycle depending on moisture conditions and the use of fungal and bacterial drugs

| Moisture conditions (factor A) | Variety (factor B) | The use of fungal and bacterial drugs (factor C) | Seed yield of the first year, kg/ha | Yield increase, kg/ha | Seed yield of the second year, kg/ha | Yield increase, kg/ha | Seed yield for two years, kg/ha | Yield increase, kg/ha |
|---|---|---|---|---|---|---|---|---|
| Irrigation | Unitro | Control (no inoculation) | 147.9 | - | 440.7 | - | 588.5 | - |
| | | Drug 1 | 156.4 | 8.6 | 490.5 | 49.8 | 646.9 | 58.4 |
| | | Drug 2 | 191.5 | 43.6 | 534.2 | 93.5 | 725.7 | 137.1 |
| | | Drug 3 | 158.6 | 10.8 | 496.9 | 56.3 | 655.6 | 67.0 |
| | | Drug 4 | 187.0 | 39.1 | 528.7 | 88.0 | 715.7 | 127.2 |
| | | Drug 5 | 173.8 | 25.9 | 481.0 | 40.3 | 654.8 | 66.2 |
| | | Drug 6 | 168.2 | 20.3 | 490.6 | 50.0 | 658.8 | 70.3 |
| | | **Average** | **169.1** | | **494.7** | | **663.7** | |
| | Elehiya | Control (no inoculation) | 180.6 | - | 515.3 | - | 695.9 | - |
| | | Drug 1 | 191.1 | 10.5 | 573.4 | 58.1 | 764.5 | 68.6 |
| | | Drug 2 | 233.9 | 53.3 | 630.1 | 114.8 | 864.0 | 168.1 |
| | | Drug 3 | 193.8 | 13.1 | 580.9 | 65.6 | 774.7 | 78.8 |
| | | Drug 4 | 229.4 | 48.8 | 612.8 | 97.5 | 842.2 | 146.3 |
| | | Drug 5 | 212.3 | 31.7 | 557.1 | 41.9 | 769.4 | 73.5 |
| | | Drug 6 | 205.8 | 25.2 | 570.3 | 55.0 | 776.0 | 80.1 |
| | | **Average** | **206.7** | | **577.1** | | **783.8** | |
| | Luyiza | Control (no inoculation) | 161.8 | - | 470.1 | - | 631.9 | - |
| | | Drug 1 | 171.2 | 9.4 | 525.7 | 55.7 | 696.9 | 65.0 |
| | | Drug 2 | 209.6 | 47.7 | 571.0 | 100.9 | 780.5 | 148.6 |
| | | Drug 3 | 173.6 | 11.8 | 533.5 | 63.4 | 707.1 | 75.2 |
| | | Drug 4 | 207.0 | 45.1 | 563.0 | 92.9 | 769.9 | 138.0 |
| | | Drug 5 | 190.2 | 28.4 | 514.1 | 44.0 | 704.3 | 72.4 |
| | | Drug 6 | 183.8 | 22.0 | 523.0 | 52.9 | 706.8 | 74.9 |
| | | **Average** | **185.3** | | **528.6** | | **713.9** | |
| | ***Average*** | | ***187,0*** | | ***533.5*** | | ***720.5*** | |
| Without irrigation | Unitro | Control (no inoculation) | 79.9 | - | 306.5 | - | 386.5 | - |
| | | Drug 1 | 86.0 | 6.1 | 336.2 | 29.7 | 422.2 | 35.8 |
| | | Drug 2 | 98.0 | 18.1 | 356.2 | 49.6 | 454.1 | 67.7 |
| | | Drug 3 | 87.6 | 7.7 | 339.5 | 32.9 | 427.1 | 40.6 |
| | | Drug 4 | 100.1 | 20.2 | 351.4 | 44.9 | 451.5 | 65.0 |
| | | Drug 5 | 82.7 | 2.8 | 331.9 | 25.4 | 414.6 | 28.2 |
| | | Drug 6 | 97.2 | 17.2 | 341.2 | 34.6 | 438.3 | 51.9 |
| | | **Average** | **90.2** | | **337.5** | | **427.8** | |
| | Elehiya | Control (no inoculation) | 106.5 | - | 357.3 | - | 463.8 | - |
| | | Drug 1 | 112.4 | 5.9 | 389.3 | 32.0 | 501.7 | 37.9 |
| | | Drug 2 | 133.3 | 26.9 | 413.8 | 56.5 | 547.2 | 83.4 |
| | | Drug 3 | 116.8 | 10.3 | 392.8 | 35.5 | 509.5 | 45.7 |
| | | Drug 4 | 130.5 | 24.1 | 404.3 | 47.0 | 534.9 | 71.1 |
| | | Drug 5 | 110.2 | 3.7 | 379.8 | 22.5 | 490.1 | 26,3 |
| | | Drug 6 | 129.5 | 23.0 | 398.3 | 41.0 | 527.8 | 64,0 |
| | | **Average** | **119.9** | | **390.8** | | **510.7** | |
| | Luyiza | Control (no inoculation) | 89.0 | - | 328.3 | - | 417.3 | - |
| | | Drug 1 | 95.7 | 6.7 | 359.7 | 31.4 | 455.4 | 38,1 |
| | | Drug 2 | 109.1 | 20.1 | 378.9 | 50.6 | 488.0 | 70,7 |
| | | Drug 3 | 97.6 | 8.6 | 362.8 | 34.5 | 460.4 | 43,1 |
| | | Drug 4 | 111.5 | 22.5 | 374.0 | 45.7 | 485.4 | 68,1 |
| | | Drug 5 | 92.1 | 3.1 | 353.3 | 25.0 | 445.5 | 28,2 |
| | | Drug 6 | 108.2 | 19.2 | 366.6 | 38.3 | 474.8 | 57,5 |
| | | **Average** | **100.5** | | **360.5** | | **461.0** | |
| | ***Average*** | | ***103,5*** | | ***363.0*** | | ***466.5*** | |
| Assessment of the significance of partial differences | | | | | | | | |
| LSD$_{05}$ | A | | 72.05 | | 81.91 | | 139.49 | |
| LSD$_{005}$ | B | | 7.77 | | 38.59 | | 40.26 | |
| LSD$_{005}$ | C | | 1.78 | | 1.91 | | 3.29 | |
| Evaluation of the significance of the main effects | | | | | | | | |
| LSD$_{005}$ | A | | 15.72 | | 17.88 | | 30.44 | |
| LSD$_{005}$ | B | | 2.08 | | 10.31 | | 10.76 | |
| LSD$_{005}$ | C | | 0.73 | | 0.78 | | 1.35 | |

Source: Own results.

The minimum seed yield was obtained on the control variant (without inoculation) with irrigation – 147.9 kg/ha in the Unitro variety, 180.6 kg/ha in the Elehiya variety and 161.8 kg/ha in the Luyiza variety, while without irrigation 79.9, 106.5 and 89.0 kg/ha, respectively. Inoculation of seeds with fungal and bacterial drugs contributed to the increase of seed productivity, regardless of the year of life of the grass stand, variety and moisture conditions. Thus, the smallest yield increase, compared to the control, with irrigation (8.6–10.8 kg/ha in the Unitro variety, 10.5–13.1 kg/ha in the Elehiya variety and 9.4–11.4 kg/ha in the Luyiza variety) was obtained by inoculating seeds with mycorrhizal drugs (Drug 1 and Drug 3). After inoculation with Drug 5 (*Sinorhizobium*) during irrigation, the seed yield was 173.8 kg/ha in the Unitro variety, 212.3 in the Elehiya variety and 190.2 kg/ha in the Luyiza variety, which was more than when using Drug 6 by 5.6 kg/ha, 6.5 and 6.4 kg/ha, respectively. However, under conditions of natural moisture, seed productivity after inoculation with Drug 5 was lower (82.7 – Unitro, 110.2 – Elehiya and 92.1 kg/ha – Luyiza) than with mycorrhizal preparations 1 and 3 by 3.3–4, 9 kg/ha, 2.1–6.5 and 3.6–5.5 kg/ha and Drug 6 – 14.4, 19.2 and 16.1 kg/ha, respectively. This suggests that Drug 5 is less effective under dry conditions.

The highest seed yield was obtained by complex (AMF and *Sinorhizobium*) inoculation of seeds with Drugs 2 and 4. Thus, with irrigation, the seed productivity when using these preparations was 187.0–191.5 kg/ha in the Unitro variety, 229.4–233.9 kg/ha in the Elehiya variety and 207.0–209.6 kg/ha in the Luyiza variety, while under conditions of natural moisture – 98.0–100.1 kg/ha, 130.5–133.3 and 109.1 –111.5 kg/ha, respectively.

In the second year of life (2019–2020), the lowest seed yield was obtained on the control variant and amounted to 440.7 kg/ha with irrigation in the Unitro variety, 515.3 kg/ha and 470.1 kg/ha in the Elehiya variety in the Luyiza variety, while under conditions of natural moisture – 306.5, 357.3 and 328.3 kg/ha, respectively.

Monoinoculation with Drugs 5 (*Sinorhizobium*), 1 and 3 (AMF) and inoculation with multicomponent bacterial Drug 6 helped to increase seed yield, compared to the control, when irrigated by 40.32–56.27 kg/ha in the Unitro variety, 41.9–65 ,6 – Elehiya and 44.0–63.4 kg/ha in the Luyiza variety and 25.4–34.6, 22.5–41.0 and 25.0–38.3 kg/ha, respectively, in conditions natural hydration.

The highest seed yield was obtained by complex (AMF and *Sinorhizobium*) inoculation of seeds with Drugs 2 and 4. Thus, with irrigation, the seed productivity when using these Drugs was 528.7–534.2 kg/ha in the Unitro variety, 612.8–630.1 kg/ha in the Elehiya variety and 563.0–571.0 kg/ha in the Luyiza variety, while under conditions of natural moisture – 351.4–356.2 kg/ha, 404.3–413.8 and 374.0 –378.9 kg/ha, respectively.

In the sum of two years, the lowest seed yield was also obtained on the control variant (without inoculation) and amounted to 588.5 kg/ha with irrigation in the Unitro variety, 695.9 in the Elehiya variety and 631.9 in the Luyiza variety, under conditions of natural moisture – 386.5, 463.8 and 417.3 kg/ha, respectively. The highest seed productivity under complex inoculation (Drug 2 and Drug 4), which amounted to 715.7–725.7 kg/ha with irrigation in the Unitro variety, 842.2–864.0 kg/ha in the Elehiya variety and 769.9–780.5 kg/ha in the Luyiza variety, while under conditions of natural moisture – 451.5–454.1 kg/ha, 534.9–547.2 and 485.4–488.0 kg/ha, respectively.

Our studies confirm the studies of various scientists on other agricultural crops that synergism is observed in the interaction between AMF and PGPR, i.e. they complement each other, reducing the negative consequences caused by abiotic stresses, improving the growth and development of plants, and, accordingly, increasing their productivity [4, 10, 11, 13, 14, 20, 44].

The use of modern technological methods of growing crops made it possible to obtain high and stable yields, but they must be economically feasible. Calculating the economic efficiency of growing alfalfa for seeds for two years (the first year of the life of the grass stand and the second), the best indicators were obtained with irrigation.

Table 2. Economic assessment of the cultivation of seeds of alfalfa varieties per cycle depending on the conditions of moisture and the use of fungal and bacterial drugs ( 1 kg of seeds – €3.75)

| Moisture conditions (factor A) | Variety (factor B) | The use of fungal and bacterial drugs (factor C) | Seed yield, kg/ha | The cost of the obtained products, €/ha | Costs per 1 ha, € | Cost of 1 kg, € | Conditionally net profit, €/ha | Profitability level, % |
|---|---|---|---|---|---|---|---|---|
| Irrigation | Unitro | Control (no inoculation) | 588.5 | 2,207.03 | 907.91 | 1.54 | 1,299.13 | 143 |
| | | Drug 1 | 646.9 | 2,425.91 | 912.88 | 1.41 | 1,513.03 | 166 |
| | | Drug 2 | 725.7 | 2,721.25 | 942.16 | 1.30 | 1,779.09 | 189 |
| | | Drug 3 | 655.6 | 2,458.38 | 915.22 | 1.40 | 1,543.16 | 169 |
| | | Drug 4 | 715.7 | 2,683.88 | 947.13 | 1.32 | 1,736.75 | 183 |
| | | Drug 5 | 654.8 | 2,455.38 | 913.16 | 1.39 | 1,542.22 | 169 |
| | | Drug 6 | 658.8 | 2,470.53 | 917.91 | 1.39 | 1,552.63 | 169 |
| | | **Average** | **663.7** | **2,488.91** | **922.33** | **1.39** | **1,566.57** | **170** |
| | Elehiya | Control (no inoculation) | 695.9 | 2,609.59 | 915.53 | 1.32 | 1,694.06 | 185 |
| | | Drug 1 | 764.5 | 2,866.72 | 921.22 | 1.20 | 1,945.50 | 211 |
| | | Drug 2 | 864.0 | 3,239.97 | 951.97 | 1.10 | 2,288.00 | 240 |
| | | Drug 3 | 774.7 | 2,904.94 | 923.69 | 1.19 | 1,981.25 | 214 |
| | | Drug 4 | 842.2 | 3,158.13 | 956.13 | 1.14 | 2,202.00 | 230 |
| | | Drug 5 | 769.4 | 2,885.22 | 921.31 | 1.20 | 1,963.91 | 213 |
| | | Drug 6 | 776.0 | 2,910.06 | 926.28 | 1.19 | 1,983.78 | 214 |
| | | **Average** | **783.8** | **2,939.23** | **930.88** | **1.19** | **2,008.36** | **216** |
| | Luyiza | Control (no inoculation) | 631.9 | 2,369.66 | 910.97 | 1.44 | 1,458.69 | 160 |
| | | Drug 1 | 696.9 | 2,613.44 | 916.44 | 1.32 | 1,697.00 | 185 |
| | | Drug 2 | 780.5 | 2,926.94 | 946.06 | 1.21 | 1,980.88 | 209 |
| | | Drug 3 | 707.1 | 2,651.47 | 918.91 | 1.30 | 1,732.56 | 189 |
| | | Drug 4 | 769.9 | 2,887.28 | 951.00 | 1.24 | 1,936.28 | 204 |
| | | Drug 5 | 704.3 | 2,641.06 | 916.66 | 1.30 | 1,724.41 | 188 |
| | | Drug 6 | 706.8 | 2,650.50 | 921.34 | 1.30 | 1,729.16 | 188 |
| | | **Average** | **713.9** | **2,677.19** | **925.91** | **1.30** | **1,751.28** | **189** |
| | ***Average*** | | ***720,5*** | ***2,701.78*** | ***926.37*** | ***1.30*** | ***1,775.40*** | ***191*** |
| Without irrigation | Unitro | Control (no inoculation) | 386.5 | 1,449.22 | 599.63 | 1.55 | 849.59 | 142 |
| | | Drug 1 | 422.2 | 1,583.28 | 603.34 | 1.43 | 979.94 | 162 |
| | | Drug 2 | 454.1 | 1,703.00 | 628.94 | 1.39 | 1,074.06 | 171 |
| | | Drug 3 | 427.1 | 1,601.59 | 605.31 | 1.42 | 996.28 | 165 |
| | | Drug 4 | 451.5 | 1,693.09 | 634.31 | 1.40 | 1,058.78 | 167 |
| | | Drug 5 | 414.6 | 1,554.81 | 601.75 | 1.45 | 953.06 | 158 |
| | | Drug 6 | 438.3 | 1,643.66 | 608.53 | 1.39 | 1,035.13 | 170 |
| | | **Середнє** | **427.8** | **1,604.09** | **611.69** | **1.43** | **992.41** | **162** |
| | Elehiya | Control (no inoculation) | 463.8 | 1,739.25 | 604.97 | 1.30 | 1,134.28 | 187 |
| | | Drug 1 | 501.7 | 1,881.25 | 608.66 | 1.21 | 1,272.59 | 209 |
| | | Drug 2 | 547.2 | 2,051.88 | 635.25 | 1.16 | 1,416.63 | 223 |
| | | Drug 3 | 509.5 | 1,910.75 | 611.28 | 1.20 | 1,299.47 | 213 |
| | | Drug 4 | 534.9 | 2,005.72 | 640.28 | 1.20 | 1,365.44 | 213 |
| | | Drug 5 | 490.1 | 1,837.72 | 607.38 | 1.24 | 1,230.34 | 203 |
| | | Drug 6 | 527.8 | 1,979.22 | 614.78 | 1.16 | 1,364.44 | 222 |
| | | **Average** | **510.7** | **1,915.11** | **617.51** | **1.21** | **1,297.60** | **210** |
| | Luyiza | Control (no inoculation) | 417.3 | 1,564.88 | 601.81 | 1.44 | 963.06 | 160 |
| | | Drug 1 | 455.4 | 1,707.75 | 605.75 | 1.33 | 1,102.00 | 182 |
| | | Drug 2 | 488.0 | 1,829.97 | 631.28 | 1.29 | 1,198.69 | 190 |
| | | Drug 3 | 460.4 | 1,726.47 | 607.66 | 1.32 | 1,118.81 | 184 |
| | | Drug 4 | 485.4 | 1,820.31 | 636.66 | 1.31 | 1,183.66 | 186 |
| | | Drug 5 | 445.5 | 1,670.47 | 603.97 | 1.36 | 1,066.50 | 177 |
| | | Drug 6 | 474.8 | 1,780.44 | 611.09 | 1.29 | 1,169.34 | 191 |
| | | **Average** | **461.0** | **1,728.61** | **614.03** | **1.33** | **1,114.58** | **181** |
| | ***Average*** | | ***466.5*** | ***1,749.27*** | ***614.41*** | ***1.33*** | ***1,134.86*** | ***185*** |

Source: Own results.

Thus, under these conditions, the cost price was 1.30 €/kg, conditional net profit – 1,775.40 €/ha, while without irrigation – 1.33 €/kg and 1,134.86 €/ha, respectively (Table 2).

The highest seed productivity was characterized by the Elehiya variety, which, when irrigated, had a seed cost of 1.19 €/kg, conditional net profit of 2,008.36 €/ha, under conditions of natural moisture 1.21 and 1,297.60, respectively.

Among the inoculants, the lowest cost price and the largest conditional net profit were obtained with the use of drug 2, which amounted to 1.30 €/kg and 1,779.09 €/ha for irrigation in the Unitro variety, 1.10 €/kg and 2,288.00 for the Elehiya variety €/ha and 1.21 €/kg and 1,980.88 €/ha in the Luyiza variety. Under conditions of natural moisture, the values of these indicators in alfalfa varieties were: 1.39 and 1,074.06, 1.16 and 1,416.63 and 1.29 €/kg and 1,198.69 €/ha, respectively.

## CONCLUSIONS

Inoculation of seeds with fungal and bacterial drugs contributed to the increase of seed productivity, regardless of the year of life of the grass stand, variety and moisture conditions. However, the highest seed yield under irrigation is 715.7–864.0 kg/ha and under natural moisture 451.5–547.2 kg/ha, and, accordingly, the lowest cost price is 1.10–1.32 €/kg and 1.16 -1.40 €/kg and the highest profit of 1,736.75–2,288.00 €/ha and 1,058.78–1,416.63 €/ha, respectively, was obtained by complex (AMF and *Sinorhizobium*) seed inoculation.

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