**Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development**
**Vol. 25, Issue 2, 2025**
**PRINT ISSN 2284-7995, E-ISSN 2285-3952**

# WHEAT AND PRODUCT LOSSES AND THEIR IMPACTS ON THE POPULATION'S NUTRITION

**Stela TODOROVA[1], Kaloyan HARALAMPIEV[2]**

[1]Agricultural University of Plovdiv, 12, Mendeleev Blvd, Plovdiv, Bulgaria, E-mail: stelatodorova_au@hotmail.com
[2]Sofia University "St. Kliment Ohridski", 15,TzarOsvoboditel Blvd, 1504 Sofia, Bulgaria, E-mail: k_haralampiev@phls.uni-sofia.bg

***Corresponding author***:stelatodorova_au@hotmail.com

***Abstract***

*Reducing food loss and waste is a key part of Sustainable Development Goal (SDG) 12 on Responsible Consumption and Production. Specifically, target 12.3 aims to "halve per capita global food waste at the retail and consumer levels by 2030, and reduce food losses along production and supply chains, including post-harvest losses."The main hypothesis is that per capita losses of wheat and products influence the population's nutrition, with a mediation effect of per capita supply. Mediation analysis will be performed using the Food Agricultural Organization statistical database, in which losses from wheat and its products are independent variables. The dependent variables relate to measuring population nutrition, and the mediator variables measure food supply per capita.Various research methods, such as the mediation analysis, Augmented Dickey-Fuller test and desktop research, have been applied. Before the application of mediation analysis, a time series stationarity test was made.*
*The study's results show that per capita losses of wheat and products do not directly or indirectly affect the "Average Dietary Energy Adequacy" and the "Prevalence of Undernourishment." However, per capita losses directly affect the "Prevalence of Obesity" among the adult population. The indicators "Average Dietary Energy Adequacy" and "Prevalence of Undernourishment" are independent of the mediator variables.*

***Keywords*****:** *wheat and product losses, population's nutrition, mediation analysis, Bulgaria*

## INTRODUCTION

Plant-based resources provide nearly 93% of the population's food, with cereals accounting for two-thirds of this amount. Cereals are a major source of protein and calories.Wheat is the main field crop grown in Bulgaria, sown on an area of about 10 to 15 million decares each year.The average yield of 570 kg/dca with 99% harvested areas with wheat – this is indicated by the latest operational data of the Ministry of Agricultureand Food (MAF) for Bulgaria [12]. Bread, which is one of the staple foods of humanity, is made primarily from wheat flour. It is also used to make various baked goods such as pasta, biscuits, and others.Wheat flour is also used in the preparation of beer, some high-alcohol beverages and even biogas.
Wheat is also a staple for governments, whose ability to remain in power and control the masses depends on their ability to feed their populations, according to an analysis prepared by analysts for the financial portal Investing.com. Wheat futures' dynamics reflect Ukraine's military conflict and the unstable geopolitical situation. Rising prices warn of the risks of famine in parts of the world and even mass discontent, which could further exacerbate the problems caused by the conflict in Ukraine. Since time immemorial, history has developed in such a way that the rise and shortage of wheat have led to serious political consequences, as wheat is one of the main foods. Together, wheat exports from Russia and Ukraine represent one-third of the world's grain exports. Due to the fighting that has been going fertile fields in Ukraine have been turned into battlefields. The armed conflict in Ukraine will have consequences far beyond the borders of both sides, which could force the population of many countries in the world to be prepared for famine. The biggest threat in this direction is for Africa and the developing world, where poverty and hunger are likely to get worse. China and India, the two most populouscountries in the world, could face food shortages. Prices in the US and Europe, however, will likely "skyrocket," further

increasing inflation, which was already at its highest level in 40 years, even before the conflict in Ukraine.

The world's population is growing continuously and meeting food needs is essential. It is believed that losses at various stages after harvest remain exceptionally high. Therefore, reducing these losses would lead to more food for the population and more efficient use and management of natural resources and farmers' livelihoods.Cereals cause the highest post-harvest losses in terms of calorific value of all agricultural crops. Up to 50%–60% of cereals can be lost during the storage stage alone due to technical inefficiencies. Post-harvest losses occur from farm to market during the harvesting, handling, storage and distribution of food. Post-harvestlossesincludefoodlossalongthefoodsup plychainfromharvest to consumption[3].Food losses are mainly due to physical damage - rough handling, unsuitable environmental conditions, poor quality containers used for transportation and storage, poor post-harvest temperature management, and lack of access to facilities and equipment for proper refrigeration, foodprocessing, orstorage[10].

The FAO defines food security as "a situation in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2011) [5].One-third of foodcrops are lost yearly in the world. Theworldpopulationhasbeenpredicted to increase to 9.1 billionbytheyear 2050, hence, a 70 percentincreaseinfoodisneededinthefuture (FAO, 2009) [6].

The impact of the COVID-19 pandemic on the agricultural sector of most countries has led to a decline in production [2], therefore the lower production needs to be protected from post-harvest losses. According to Dharmathilake et al., the availability of sufficient food is linked to the overall ability of the agricultural system to meet food demand [4].

The preventing food loss and waste has become a global issue. Solving this major societal problem is possible by improving education in this area, improving raw material processing technologies, and improving transport and storage facilities. This activity should involve the entire agricultural food production and supply chain.In addition, collecting data, and comparable data across countries, is essential. Data on losses for certain products can be found in various data bases, but for the individual stages of the supply chains of a particular product is very difficult, if not impossible. There are also no scientific studies on the impact of these losses on the nutrition of the population.

The main hypothesis in the study is that per capita losses of wheat and products affect the population's nutrition with a mediating effect on per capita supply.

## MATERIALS AND METHODS

The main hypothesis is that per capita losses of wheat and products influence nutrition of population, with mediation effect of per capita supply.

The rationale for this hypothesis is as follows:

• Greater "Losses per capita" will lead to lower per capita supply;

• Greater per capita supply will lead to better nutrition of population;

• And as a result – greater "Losses per capita" will lead to worse nutrition of the population.

The data source is the Food and Agriculture Organization (FAO).

Data from Food Balances from 2010 until now [7], Food Balances until 2013 [8] and Food Security and Nutrition[9] were used. The data refer to the period 2000-2022.

Food losses are measured in metric tons. To achieve comparability between them and supply per capita, the food losses are recalculated in kilograms per capita.

For per capita supply, all four FAO indicators were used:

• "Food Supply Quantity (kg/capita/year)";
• "Food Supply (kcal//capita/day)";
• "Protein Supply Quantity (g/capita/day)";
• "Fat Supply Quantity (g/capita/day)".

Three indicators were used as a measure of population nutrition:

- "Average Dietary Energy Supply Adequacy"
- "Prevalence of Undernourishment"

- "Prevalence of Obesity in the Adult Population"

The prevalence of undernutrition in one direction and the prevalence of obesity in the opposite direction are in fact negative effects of nutrition of the population.

Since the information for "Average Dietary Energy Supply Adequacy" and "Prevalence of Undernourishment"is in the form of 3-year averages, all other indicators were also calculated as 3-year averages. In this calculation, a weighted arithmetic mean was used, with the number of population in the respective year used as weights. As a result, 21 3-year intervals were obtained – from 2000-2002 to 2020-2022.

The particular indicators we have used to measure food losses, per capita supply and nutrition of population, lead to the concretization of the main hypothesis (Fig. 1).

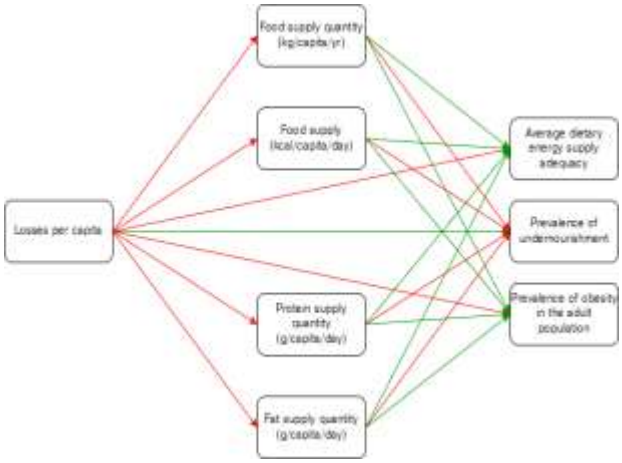


Fig. 1. Relationships between losses per capita and nutrition of population
Source: Authors' own conception.

Expected positive relations are marked in green, while expected negative relations are marked in red.

Mediation analysis was used to model these relationships. This analysis allows the estimation of both the direct and indirect impacts of the independent variable on the dependent variables.Mediation analysis is a statistical method used to understand the mechanisms by which an independent variable influences a dependent variable through a mediator variable. By including the mediator in the analysis, we gain a deeper understanding of the causal chain of events [13].

Mediation analysis involves two types of regression equations. The first one shows the influence of the independent and mediating variables together on the independent variable. The second one shows the influence of the independent variables on the mediator variables. [14]

In our case these two types of equations are:

$$\hat{Y}_i = a_i + b_i X + \sum_{j=1}^{4} c_{ij} M_j \ (i = 1,2,3)$$

$$\hat{M}_j = \alpha_j + \beta_j X \ (j = 1,2,3,4)$$

Where:

$Y_1$ is "Average Dietary Energy Supply Adequacy"

$Y_2$ is "Prevalence of Undernourishment"

$Y_3$ is "Prevalence of Obesity in the Adult Population"

$X$ are "Losses per capita"

$M_1$ is "Food Supply Quantity (kg/capita/year)";

$M_2$ is "Food Supply (kcal//capita/day)";

$M_3$ is "Protein Supply Quantity (g/capita/day)";

$M_4$ is "Fat Supply Quantity (g/capita/day)"

## RESULTS AND DISCUSSIONS

Before the application of mediation analysis, a time series stationarity test was made. For this purpose, the Augmented Dickey-Fuller (ADF) test was used (Table 1), which is the most popular and most commonly used Unit Root test.The test results indicated:

• The time series of "Prevalence of Undernourishment" is non-stationary, but the time series of the first differences are stationary. Therefore, the first differences are used in the analysis;

•The time series of "Losses per capita", "Food Supply Quantity (kg/capita/year)", "Food Supply (kcal//capita/day)", "Protein Supply Quantity (g/capita/day)", "Fat Supply Quantity (g/capita/day)", "Average Dietary Energy Supply Adequacy" and "Prevalence of Obesity in the Adult Population" are non-stationary and the time series of the first differences are also non-stationary. However, the time series of the second differences are stationary, so the second differences are used in the analysis.

Table 1. Augmented Dickey-Fuller test*

| Variable | Level – intercept | | First differences – intercept | | Second differences – intercept | |
|---|---|---|---|---|---|---|
| | Test statistics | *p*-value | Test statistics | *p*-value | Test statistics | *p*-value |
| Losses per capita | -2.09 | 0.252 | -2.77 | 0.084 | **-10.65** | **0.000** |
| Food Supply Quantity (kg/capita/year) | -1.68 | 0.425 | -2.84 | 0.072 | **-3.84** | **0.010** |
| Food Supply (kcal//capita/day) | -2.10 | 0.246 | -2.20 | 0.214 | **-4.49** | **0.003** |
| Protein Supply Quantity (g/capita/day) | -2.05 | 0.264 | -2.29 | 0.185 | **-4.42** | **0.003** |
| Fat Supply Quantity (g/capita/day) | -1.67 | 0.431 | -1.30 | 0.607 | **-3.30** | **0.031** |
| Average Dietary Energy Supply Adequacy | 4.12 | 1.000 | -1.54 | 0.492 | **-5.99** | **0.000** |
| Prevalence of Undernourishment | 0.55 | 0.984 | **-3.23** | **0.034** | | |
| Prevalence of Obesity in the Adult Population | -1.37 | 0.573 | -1.94 | 0.310 | **-4.13** | **0.006** |

* Null hypothesis is that time series have unit root, i.e., time series are non-stationary.
Source: Own calculation.

Table 2. Estimations of coefficients of mediation analysis

| Independent variable | Dependent variable | Unstandardized coefficient | *z*-statistics | *p*-value |
|---|---|---|---|---|
| Food Supply Quantity (kg/capita/year) | Average Dietary Energy Supply Adequacy | -0.061 | -0.374 | 0.708 |
| Food Supply (kcal//capita/day) | Average Dietary Energy Supply Adequacy | -0.051 | -0.224 | 0.823 |
| Protein Supply Quantity (g/capita/day) | Average Dietary Energy Supply Adequacy | 2.009 | 0.302 | 0.763 |
| Fat Supply Quantity (g/capita/day) | Average Dietary Energy Supply Adequacy | -0.841 | -0.268 | 0.789 |
| Losses per capita | Average Dietary Energy Supply Adequacy | 0.022 | 0.637 | 0.524 |
| Food Supply Quantity (kg/capita/year) | Prevalence of Undernourishment | 0.070 | 1.182 | 0.237 |
| Food Supply (kcal//capita/day) | Prevalence of Undernourishment | -0.036 | -0.441 | 0.659 |
| Protein Supply Quantity (g/capita/day) | Prevalence of Undernourishment | 0.712 | 0.294 | 0.769 |
| Fat Supply Quantity (g/capita/day) | Prevalence of Undernourishment | 0.552 | 0.485 | 0.628 |
| Losses per capita | Prevalence of Undernourishment | -0.003 | -0.216 | 0.829 |
| Food Supply Quantity (kg/capita/year) | Prevalence of Obesity in the Adult Population | -0.004 | **-2.631** | **0.009** |
| Food Supply (kcal//capita/day) | Prevalence of Obesity in the Adult Population | 0.013 | **5.854** | **0.000** |
| Protein Supply Quantity (g/capita/day) | Prevalence of Obesity in the Adult Population | -0.394 | **-5.970** | **0.000** |
| Fat Supply Quantity (g/capita/day) | Prevalence of Obesity in the Adult Population | -0.094 | **-3.014** | **0.003** |
| Losses per capita | Prevalence of Obesity in the Adult Population | 0.001 | **3.126** | **0.002** |
| Losses per capita | Food Supply Quantity (kg/capita/year) | 0.096 | 0.993 | 0.321 |
| Losses per capita | Food Supply (kcal//capita/day) | 0.095 | 0.125 | 0.900 |
| Losses per capita | Protein Supply Quantity (g/capita/day) | 0.002 | 0.097 | 0.922 |
| Losses per capita | Fat Supply Quantity (g/capita/day) | 0.006 | 1.127 | 0.260 |

Source: Own calculation.

The results of the mediation analysis evaluation are presented inTable 2 below.

From the revealed relationships in Fig. 2, several conclusions can be drawn:

• "Losses per capita" influence neither directly nor indirectly "Average Dietary Energy Supply Adequacy" and "Prevalence of Undernourishment".

• "Losses per capita" influence "Prevalence of Obesity in the Adult Population" ( $z = 3.13, p = 0.002$ ), which is contrary to preliminary expectations.

• "Average Dietary Energy Supply Adequacy" and "Prevalence of Undernourishment" do not dependent on mediator variables.

• "Prevalence of Obesity in the Adult Population" depends on all mediator variables.

Obtained statistically significant relationships are presented in Fig. 2.

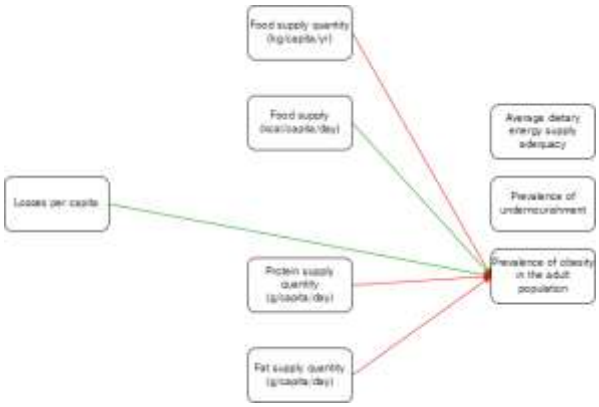


Fig. 2. Statistically significant relationships identified through the mediation analysis

Source: Authors' own conception.

○ Relationships between "Prevalence of Obesity in the Adult Population" on the one hand and "Food Supply Quantity (kg/capita/year)" ( $z = -2.63, p = 0.009$ ), "Protein Supply Quantity (g/capita/day)" ($z = -5.97, p = 0.000$) and "Fat Supply Quantity (g/capita/day)" ($z = -3.01, p = 0.003$) on the other hand are negative – greater values of mediator variables lead to a lower "Prevalence of Obesity in the Adult Population", which is contrary to preliminary expectations.

○ Relationship between "Prevalence of Obesity in the Adult Population" and "Food Supply (kcal//capita/day)" is positive – greater values of mediator variable lead to a higher "Prevalence of Obesity in the Adult Population" ( $z = 5.85, p = 0.000$ ), which coincides with preliminary expectations.

It is noteworthy that all results that contradict preliminary expectations refer to indicators that are measured in kilograms or grams per capita. This is a key to a possible explanation of these contradictions. The change of prevalence of obesity could be related not to the quantity, but to the quality of food, proteins and fats. It is possible that a higher amount of high-quality food, protein and fat does not lead to the prevalence of obesity, as does a lower amount of protein and fat, but of poorer quality. An additional argument in this direction is that a greater supply of food, but measured in kilocalories, leads to a greater prevalence of obesity.

*Reducing post-harvest losses of cereals - a way to increase food security*

Grain storage on the farm is done in several ways:

•open warehouse - the most traditional, well-known and popular way to store;

•iron silos (personally built premises with different storage capacities) - the second most popular storage method;

•plastic sleeves (big bags) - in recent years a method of storing grain that has gained great popularity;

•quick-installation structures (Crop circles) - widely used in grain-producing countries such as the USA and Canada.

Among the advantages of grain storage warehouses are the possibility of re-equipping and adapting old premises (barns), no significant investments are required, there is a possibility of separate storage of even small quantities of grain. Storing grain in open warehouses poses risks: poor ventilation, the flooring is not always of high quality, additional equipment and labor costs are incurred when transferring, and the inability to fill the warehouse to full capacity.

However, after modernization (equipment with ventilation ducts, sloping floors, etc.), the open warehouse is much more suitable for storage. The risks of storing grain in structures of the quick-assembly type are: poor protection of the product from environmental influences, high percentage of losses during storage, need for live security (when located directly in the

field), and short shelf life. Despite the strong supporters of storage in plastic sleeves, this technology is accompanied by a number of risks: the need for careful preparation of the site, expensive disposable sleeves, the special equipment for loading and unloading grain, the need for protection, control of birds and rodents, seeds lose their germination, workers must have certain skills.Amongtheadvantages of the method, the following can be noted: the technology is relatively affordable for grain producers; it allows for long-term storage without loss of grain quality; the grain is stored tightly; significant cost savings compared to silosOne way to reduce the costs, and therefore the risks of grain storage, is to cool it. Before leaving for storage (after acceptance, further processing, and loading), the grain can be cooled. This will reduce the loss of dry weight, slow down the development of pests, and avoid the development of mold (mycotoxins). Cooled grain can be stored with a humidity of 1-1.5% higher than recommended. The residual moisture will be removed from the grain during the cooling process. Cooled grain does not need to be moved or poured, since it does not heat up. All this allows to avoid grain losses due to injuries, no additional energy consumption is required. In addition, we have additional space in the storage capacities. All types of cereals can be cooled.

## CONCLUSIONS

The food production and consumption system is characterized by three dimensions - financial, environmental, and social. This requires measures to overcome food loss to be directed at each of these levels. It is necessary to take measures to change the attitude toward foodloss, this is the only way to ensure sustainable food production for the growing world population. The production and consumption of agricultural products have a significant impact on the environment, as they intensively use limited natural resources, cause the formation of greenhouse gases, pollute with the use of plant protection products and depletes oil nutrients such as nitrogen and phosphorus. Therefore, when the food produced from them is lost or wasted, the natural resources used for its production are also lost, leading to negative economic and environmental impacts. In this regard, it is necessary to turn to the use of organic fertilizers and preparations, and as [11] notes, organically fertilized plants (Vitaorganic) have significant biological potential and lead to the accumulation of amounts of dry matter and total sugars similar to those grown with mineral fertilization.

One of the Sustainable Development Goals - Goal 12.3, requires that by 2030, not only food losses along food production and supply chains but also post-harvest losses be reduced globally.

Short food supply chains(SFSCs) will play an important role in achieving this goal.

## ACKNOWLEDGEMENTS

This research work was carried out with the support of the BNSF [КП-06-КОСТ/15, 2024]

## REFERENCES

[1]Adams, R.S., Ishler, V.A., 2009, Trouble-shooting problems with low milk production. Dairy and Animal Science, 4(1), 98–16.www.das.psu.edu/teamdairy, Accessed on June 3, 2024.

[2]Adebisi, O.A., Adebisi, L.O., Ibrahim., F., Omofaiye, A.M., Jonathan, A., 2021, Covid-19 Lockdown:ImplicationonCommodity Food Price and Household Food Security in Kwara State, Nigeria. International Journalof Agricultural Science Research and Technology in Education and Education System, 11(3), pp. 173-179.

[3]Aulakh, J., Regmi, A., Fulton, J.R., Alexander, C., 2013, Estimating post-harvest food losses: developing a consistent global estimation framework. In: Proceedings of the Agricultural & Applied Economics Association's2013 AAEA & CAES joint annual meeting, Washington, DC, USA, 4– 6 August 2013.

[4]Dharmathilake, N.R.D.S., Rosairo, H.S.R., Ayoni, V.D.N., Herath, R.M., 2020, Implications of Post-Harvest Losses and Acreage Response of Selected Up-Country Vegetables from Nuwara-Eliya District in Sri Lankaon Sustained Food Security.The Journal of Agricultural Sciences - Sri Lanka Vol. 15(1), 88-100. http://doi.org/10.4038/jas.v15i1.8674.

[5]Food and Agricultural Organization, 2011, Global food losses and waste: extent, causes and prevention.

[6]Food and Agricultural Organization, 2009, How to Feed the World in 2050. Rome: FAO. http://www.fao.org/fileadmin/templates/w sfs/docs/expert_paper/How_to_Feed_the_ World_in_ 2050.pdf, Accessed on 28 September 2024.

[7]Food and Agriculture Organization. Data from Food Balances from 2010 until now.https://www.fao.org/faostat/en/#data/FBS, Accessed on 5 January, 2025.
[8]Food and Agriculture Organization. Food Balances until 2013. https://www.fao.org/faostat/en/#data/FBSH, Accessed on 5 January, 2025.
[9]Food and Agriculture Organization. Food Security and Nutrition https://www.fao.org/faostat/en/#data/FSAccessed on 5 January, 2025.
[10]Kitinoja, L., 2016, Innovative small-scale postharvest technologies for reducing losses in horticultural crops.Ethiop J Appl Sci Technol 1, pp. 9–15.
[11]Kostadinov, K., Filipov, S., Shopova, N., Chipilski, R.,2024,Vegetativebehaviorofcabbagegrownwithorganicfertilization.VII International Agricultural, Biological & Life Science Conference, Edirne, Turkey, 18-20 September.
[12]Ministry of Agriculture and Food, Bulgaria.
[13]Vo, T.-T., Cashin, A., Superchi, C., Tu, P.H.T., Nguyen, T.B., Boutron, I., MacKinnon, D., Vanderweele, T., Lee, H., Vansteelandt, S., 2022, Quality assessment practice in systematic reviews of mediation studies: results from an overview of systematic reviews. Journal of Clinical Epidemiology.143, pp. 137-148.DOI: 10.1016/j.jclinepi.2021.12.013
[14]Preacher, K.J., Kelley, K., 2011, Effect Size Measures for Mediation Models: Quantitative Strategies for Communicating Indirect Effects. Psychological Methods. Vol. 16, No. 2, pp. 93–115. DOI: 10.1037/a0022658