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DEVELOPING A MODEL BASED ON A STATISTICAL ANALYSIS OF FOOD LOSS AND WASTE PATTERNS

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Abstract

Reducing food loss and waste on each level of agrifood chain is a responsible action, thus each stakeholder on the agrifood chain must create actions that are related to food waste prevention. In this matter, this paper presents an analysis of a statistical study run on a sample of respondents related to food loss and waste on a consumer level of agrifood chain. The study takes into account both quantity and quality parameters and serves as a provider of training data for a model which will be developed based on prediction. Another important aspect of the paper is related to the determination of food loss and waste economical Another crucial aspect discussed in the paper concerns identifying economic behavioural patterns associated with food loss and waste throughout various levels of the agrifood chain. This data will be instrumental in training models for those respective levels. The study emphasizes the significance of raising awareness and taking action to minimize food waste across all phases of the agricultural and food distribution process. It also emphasizes the necessity of developing models and strategies to effectively approach this challenge.

Key words**:** *food loss and waste, statistical, model, agrifood chain*

INTRODUCTION

With growing pressure to ensure a sustainable and efficient agri-food chain [3], minimizing food loss and waste has become a critical issue on both a regional [16] and global scale. This problem goes beyond just economics [6] and social impact [11]. It significantly affects the environment as well [2], by the consumption of precious resources and the contribution to greenhouse gas emissions. Furthermore, understanding the behavioral factors that contribute to food loss and waste is a key approach in tackling this challenge [10, 8].

This paper focuses on the analysis of food loss and waste behavior at the level of consumers in the agri-food chain. By conducting an extensive statistical analysis, the study seeks to gain more in-depth insights into household food management practices and identify the factors that influence the generation of food waste [7]. The study examines both quantity [1] and quality of food waste to provide a comprehensive picture of consumer food management behaviour.

An important aspect of this work is related to the use of the results of the statistical study for the development of a prediction model [9]. Various models concerning food loss and waste have been discussed in existing literature [5, 14, 15], focusing particularly on patterns of food loss and waste [4]. The forthcoming model will utilize data acquired

for training purposes and aims to forecast the extent of food loss and waste at the consumer level.

The paper will also identify and study economic behavioral patterns related to food loss and waste at other levels of the agri-food chain, thus providing additional training data for the prediction model.

This study is a continuation of the research on the topic of food loss and waste management presented in our pervious articles [12, 13.]

MATERIALS AND METHODS

This paper describes the main findings resulted after the compilation of the responses given at a questionnaire related to food waste behavioural patterns and their analysis. The questionnaire is part of the ReWaFA study, related to food loss and waste (FLW) phenomenon analysis alongside the agrifood chain. The results will be computed to construct a training dataset for an upcoming prediction model concerning food waste, the methodology of which will be briefly outlined in a section of this paper and further elaborated in future research papers. In this matter, the main purpose of the analysis presented is the determination of patterns related to food waste, especially related to the consumer component of the agrifood chain, and the computation of the main indicators that will be taken into account for a future prediction model.

The ReWaFA study analysis methodology

As said, the main purpose of the ReWaFA study is centred on the study of FLW alongside the agrifood chain. For this specific period of the study development, the research focus was set on the final components of the agrifood chain, i.e., the consuming component. This phase of the study was aimed at examining consumer behaviour concerning food loss and waste. To achieve this, an online questionnaire was employed, comprising structured inquiries regarding the frequency of food purchases, methods of food storage, the level of awareness about food waste, and other pertinent aspects of food behaviour.

The development of this phase had several steps:

S1. *The design of the questionnaire*: this step consisted in the development of the structure and morphology of the questionnaire. It was structured on specific sections, related to demographic data, consuming processes, food habits and measures taken to reduce food waste. The questions were predominantly single (category-based) and multiple-choice (preference and situational) questions and the final consideration was made using an open question.

S2.*The sampling process*: The sample of participants was selected using convenient random sampling, resulting in a total of 365 responses.

S3.*The implementation of the questionnaire*: the questionnaire was distributed online through a variety of social media platforms and via e-mail to participants from various geographical regions of Romania (according to NUTS-2 development regions), thus ensuring a relatively even distribution of responses.

S4.*The response analysis*: several direct observations were made and correlations were explored in this phase of the study.

This study examined several factors that may influence food waste behaviour, including frequency of food shopping, food storage methods, level of awareness of food waste, planning of shopping and food consumption, attitudes and eating behaviours, socio-economic level and demographic factors.

These factors were considered essential in building a classification model to better identify and understand consumer behaviour in relation to agri-food waste.

The study was conducted in accordance with ethical procedures, ensuring anonymity and confidentiality of respondents. Limitations of the study included possible sample representativeness issues and subjectivity in reporting food waste behaviour.

The prediction model methodology

The prediction model represents the exploratory phase of the model. In this context, the prediction model aims to identify specific patterns of food loss and waste associated with the consumer segment of the agrifood chain. The primary anticipated

outcomes revolve around discerning distinct patterns of the food loss and waste phenomenon during the consumption phase. For this specific purpose, the next steps were taken into consideration:

S1.*Data selection*: from all the given responses, the specific characteristics of the model will be selected.

The characteristics are the indicators that will be the base of the prediction.

S2*.Data pre-analysis*: in this step, several statistical correlations between selected data can be explored and determined. These correlations may form a categorical structure that may delimit specific behavioural patterns, used in the output process (e.g., clusters or classes as patterns, used for prediction).

S3.*Data pre-processing*: this step consists in the transformation of the selected data (e.g., normalization, encoding).

S4.*Dataset split*: the obtained dataset is split in two subsets: training set and testing set (usually in 80-20 or 70-30 proportions).

S5.*Model building*: using the selected method (either decision trees, ML-based methods or neural networks), the respective instrument is built and trained with the training data.

S6*.Model assessment*: the built model is assessed based on the determination of specific KPI indicators which are measured based on the testing data.

S7*.Model interpretation*: the resulted model is interpreted and its parameters are optimized.

In this regard, starting from specific selected characteristics believed to influence food loss and waste behaviour, and using the collected data, the patterns associated with food loss and waste are obtained, either numerical (a predicted quantity of food waste) or categorical (a cluster of food waste behavioural pattern).

RESULTS AND DISCUSSIONS

We will make an analysis related to the responses given to the built questions. The first questions are related to demographic data.

Fig. 4 presents the structure of the sample related to age categories.

We can see that the respondents situate largely in the 18-35 age category.

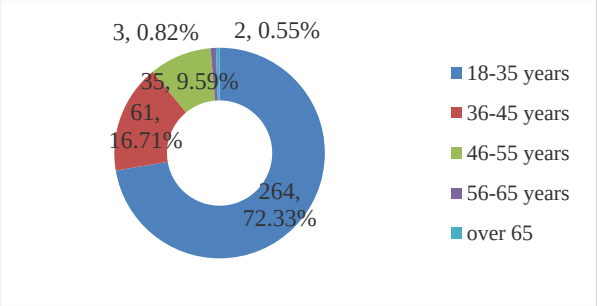


Fig. 4. The classification of respondents by age group
Source: data processing from online questionnaire.

Fig. 5 presents the classification by gender. We can observe that the structure of the sample related to gender is almost balanced, with a slight increase to feminine gender.

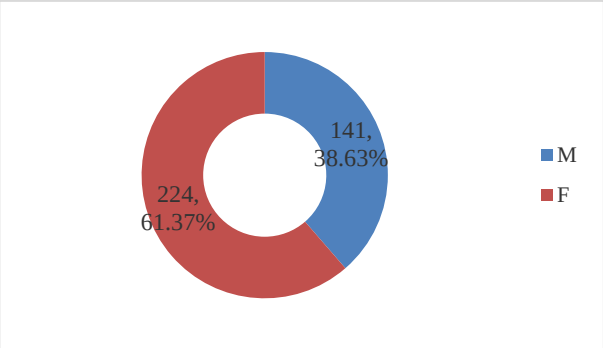


Fig. 5. The classification of respondents by gender
Source: data processing from online questionnaire.

Next, Fig. 6 presents the data related to the latest form of education of the respondents.

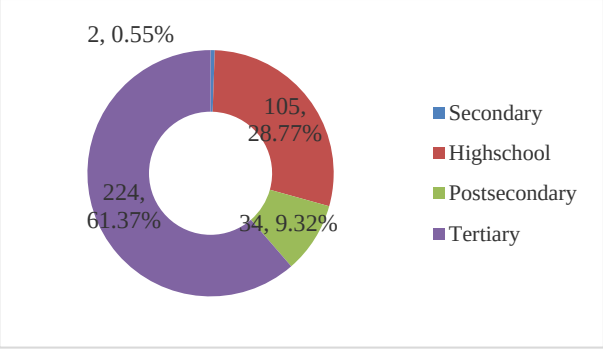


Fig. 6. The classification of respondents by latest form of education
Source: data processing from online questionnaire.

We can observe that the majority of the respondents has as latest form of completed education tertiary levels, related to university education (e.g., bachelor's degree, master's

degree).

Next, Fig. 7 presents the data related to the geographical distribution of the respondents.

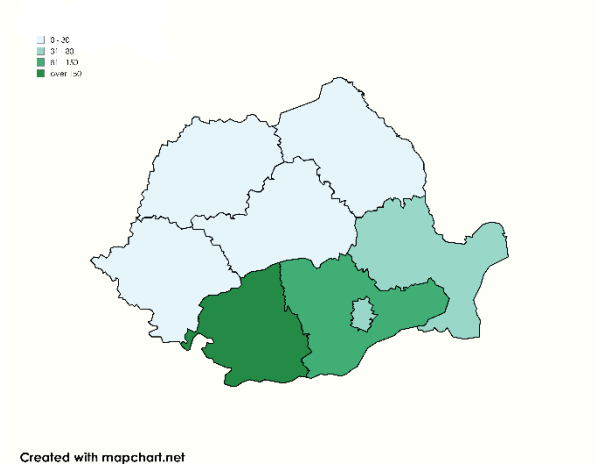


Fig. 7. The classification of respondents by NUTS-2 regions
Source: data processing from online questionnaire.

We can observe that a significant proportion of respondents originate from the South-West Oltenia development region.

Next, Fig. 8 presents the data related to the socio-economic status of respondents.

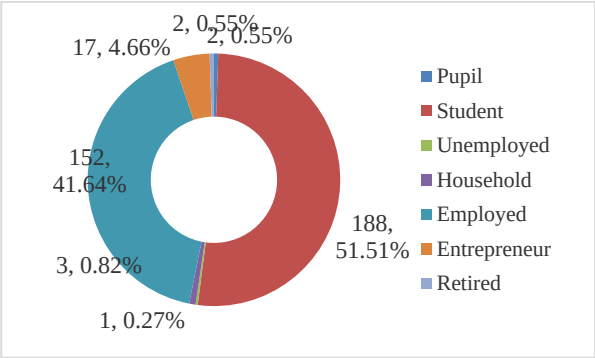


Fig. 8.The classification of respondents by income
Source: data processing from online questionnaire.

The primary two respondent categories comprise employees and students, with a minor representation from entrepreneurs.

Next, Fig. 9 presents the data related to the income of the respondents.

We can observe that the primary two income categories among the respondents correspond to incomes below Lei 5,000.

Next, Fig. 10 presents the data related to the residence of the respondents. We can observe that a slightly majority of the respondents is established in the urban environment (approximately 65%).

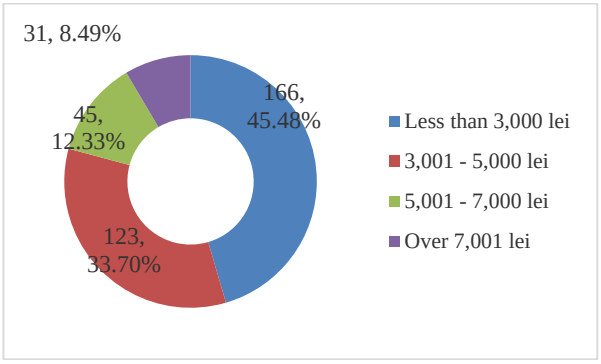


Fig. 9. The classification of respondents by income
Source: data processing from online questionnaire.

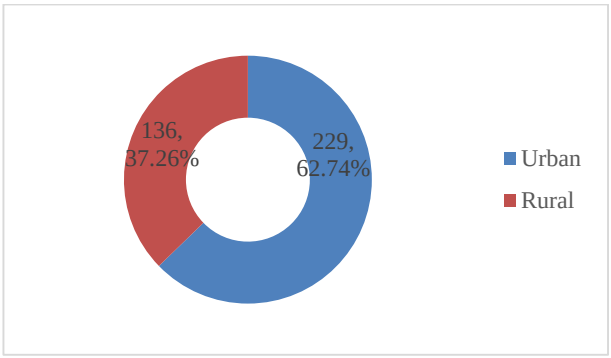


Fig. 10. The classification of respondents by residence
Source: data processing from online questionnaire.

Fig. 11 presents the frequency of the purchasing events reported to a monthly period. We can observe that many respondents have a frequent habit of buying food, resulting a predominant frequency of 6 to 8 food purchasing events per month.

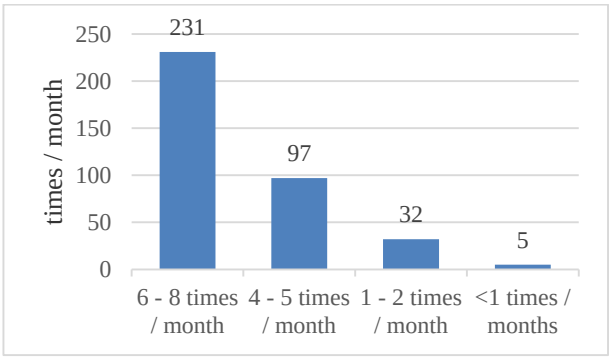


Fig. 11. The frequency of food purchase events
Source: data processing from online questionnaire.

The next graph, shown in Fig. 12, presents the amount of financial resources spent monthly on food. The majority of the respondents spend an amount of money between 500 and 1,000 lei, between 10% and 20% of the total average income, as computed based on data in Fig. 9.

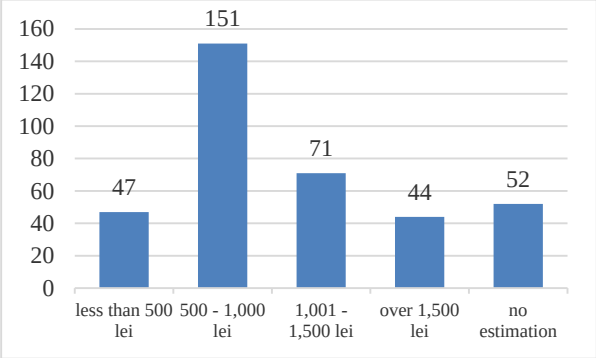


Fig. 12. The amount of money spent on food monthly
Source: data processing from online questionnaire.

Next, Fig. 13 presents the main categorical causes identified by the respondents for FLW. The three main causes are related to food that is perishable or in large amounts.

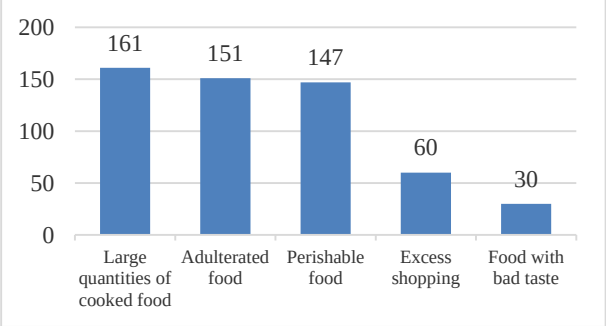


Fig. 13. The main causes of the food waste identified among the respondents
Source: data processing from online questionnaire.

In the next figure, Fig. 14, the distribution of buyers on main purchasing locations of agrifood are presented.

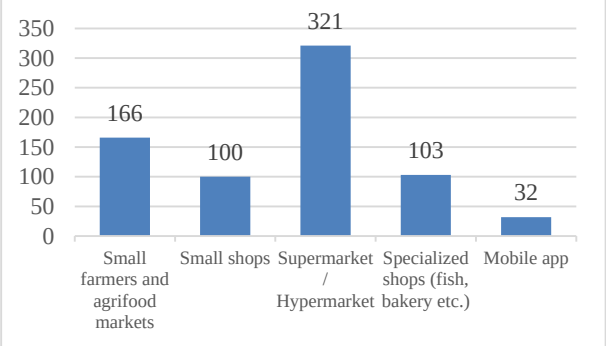


Fig. 14. The main places where respondents purchase food
Source: data processing from online questionnaire.

The vast majority of the respondents purchase their agrifood from supermarkets or hypermarkets, followed by small farmers and agrifood markets.

Fig. 15 presents the perceived amount of food waste from the total amount of purchased food.

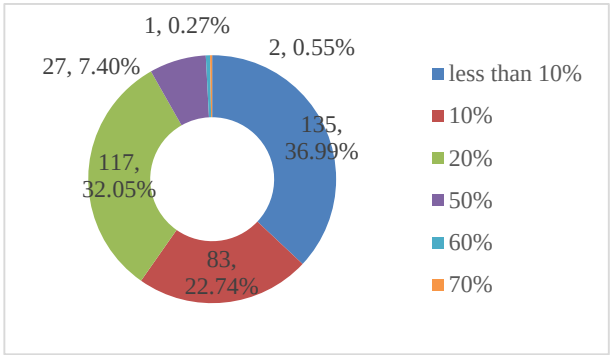


Fig. 15. The perceived percent of food waste monthly
Source: data processing from online questionnaire.

The majority of the respondents (over 90%) perceive a proportion of waste food below 20% from the total amount of purchased food.

Fig. 16 presents the amount of respondents that waste prepared or unconsumed food. The proportion of the respondents who throw prepared or unconsumed food is almost balanced with the one who does not have this habit.

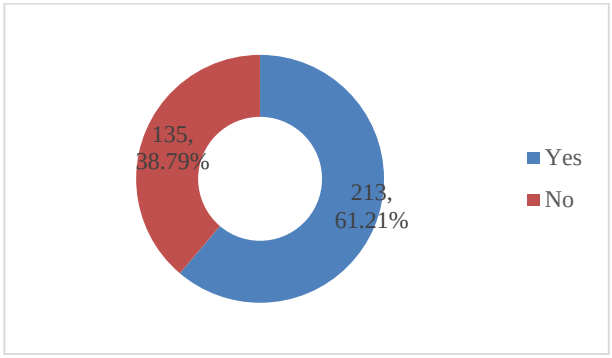


Fig. 16. Proportion of respondents who waste cooked or unconsumed food.
Source: data processing from online questionnaire.

Next, Fig. 17 presents responses related to specific clauses describing habits of food waste.

As we can see, the average respondent frequently throws away leftovers, but one seldom preserve them for a later usage. However, a part of them is frequently directed to pets. Also, the habit of purchasing food with a longer shelf life is usual and one moderately does selective recycling.

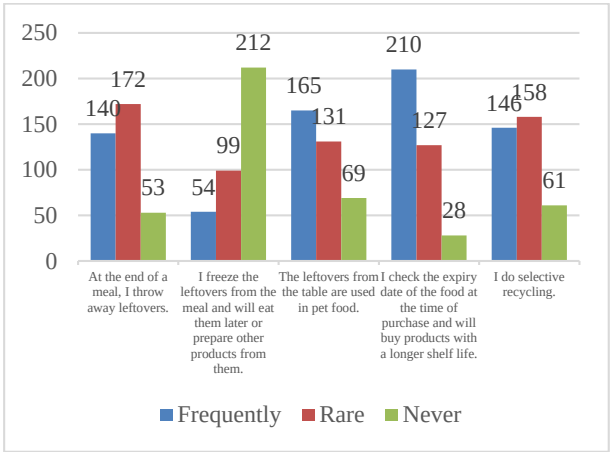


Fig. 17. Responses given to specific affirmations related to food waste
Source: data processing from online questionnaire.

Next, Fig. 18 presents the main wasted food categories. As seen, the vast majority of wasted food is related to cooked food, the rest of the categories having a balanced proportion in the food waste bin.

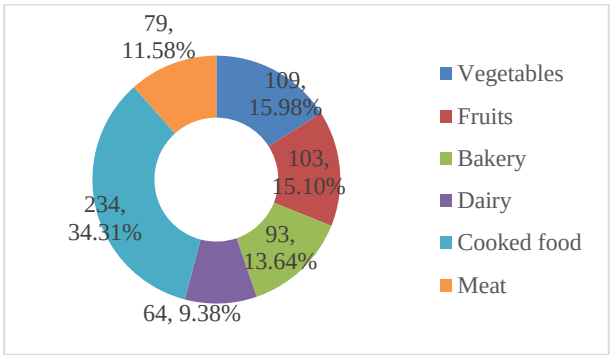


Fig. 18. The main categories of wasted food.
Source: data processing from online questionnaire.

Next, Fig. 19 presents the importance given by the respondents to specific purchasing process aspects.

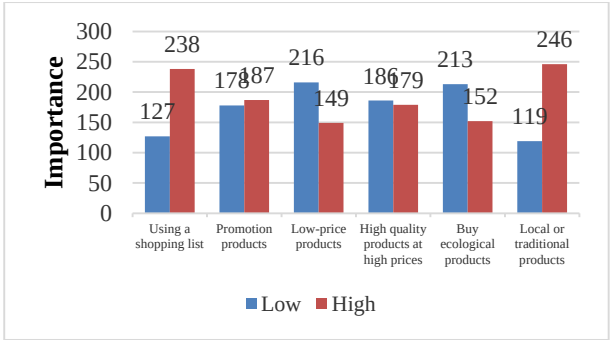
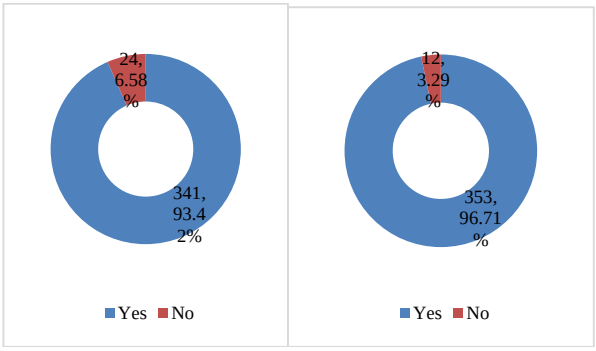


Fig. 19. Important aspects taken into account by buyers in the purchasing process
Source: data processing from online questionnaire.

As we can see, the most important aspects of the purchasing process perceived as important are the usage of a shopping list and the purchasing of local and traditional products, the least important being the purchase of the ecological products, the low price of some products and the purchase of high quality products at high prices.

Next, Fig. 20 presents approaches related to food waste behaviour.

As evident from the data, nearly 95% of the participants are aware of the food waste phenomenon, and over 95% have expressed their intention to reduce food waste on an individual basis.



(a) (b)

Fig. 20. Responses to the question: (a) Did you hear about food waste? (b) Do you want to reduce food waste in the future?
Source: data processing from online questionnaire.

Next, Fig. 21 presents chosen measures for food waste prevention. The main identified cause from the given three for the food waste is considered to be the purchase of a balanced amount of food with the individual or household needs.

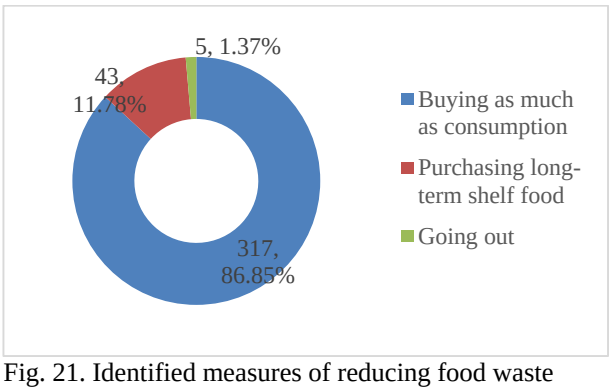


Fig. 21. Identified measures of reducing food waste quantities.
Source: data processing from online questionnaire.

Next, Fig. 22 presents the perception of food waste responsibles. The majority of the

respondents identified household consumption as the main generator of food waste, followed by supermarkets, hypermarkets and restaurants.

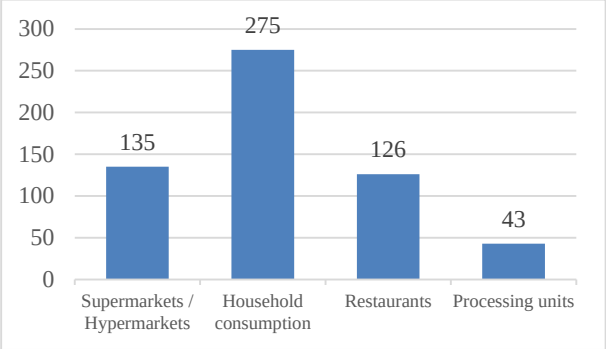


Fig. 22. Identified responsibles for food waste.
Source: data processing from online questionnaire.

Finally, Fig. 23 presents the acceptance proportion of respondents to three given affirmations.

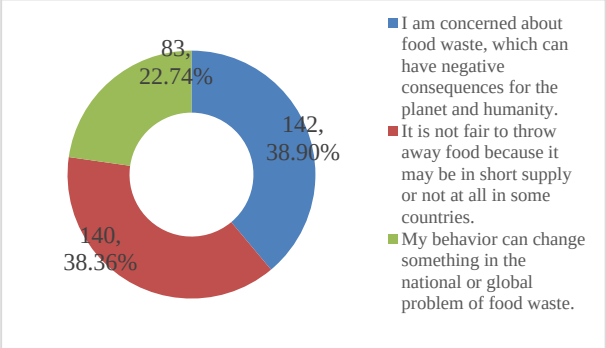


Fig. 23. Various opinions related to food waste.
Source: data processing from online questionnaire.

As observed, respondents equally consider all statements regarding the impact of food loss and waste, food balance, and personal involvement in preventing food loss and waste.

In conclusion, we can establish that that respondents are aware of the food loss and waste phenomenon and are readily inclined to personally engage in optimizing both food and financial resources.

The significance of developing a prediction model for food loss and waste cannot be overstated. It encompasses a complex process that includes gathering and analyzing data, establishing prediction goals, and selecting the suitable machine learning algorithm. The ultimate goal of this model is to forecast and measure the extent of food loss and waste across various settings, spanning from individual households to a global scale. It can be used to identify key factors influencing food waste and to propose effective strategies and interventions to reduce it. The process of creating such a model involves analyzing and interpreting data, developing and evaluating predictive models, and integrating the results into decisions and policies relevant to food waste management. The detailed description of the model and results after its implementation will be presented in a future research paper.

CONCLUSIONS

The study presented offers an analysis of a statistical study undertaken on a sample of respondents concerning food loss and waste within the agri-food chain at the consumer level. It encompasses both quantitative and qualitative parameters and serves as a provider of training data for a forthcoming model intended for prediction purposes. Another significant facet of the document pertains to establishing economic behavioural models concerning food loss and waste across other levels of the agri-food chain. These models will serve as training data for the aforementioned model across the remaining levels of the agri-food chain.

In essence, the findings highlight the importance of awareness and action in reducing food waste at all levels of the agri-food chain, as well as the need to develop specific models and strategies to address this complex issue. Through the collection and analysis of data, the study contributes to the understanding of food waste behaviour and the identification of key factors that influence this phenomenon, thus providing a solid basis for developing effective solutions and policies to combat food waste.

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