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EMPIRICAL ANALYSIS OF FOOD LOSSES AND WASTE IN UKRAINE

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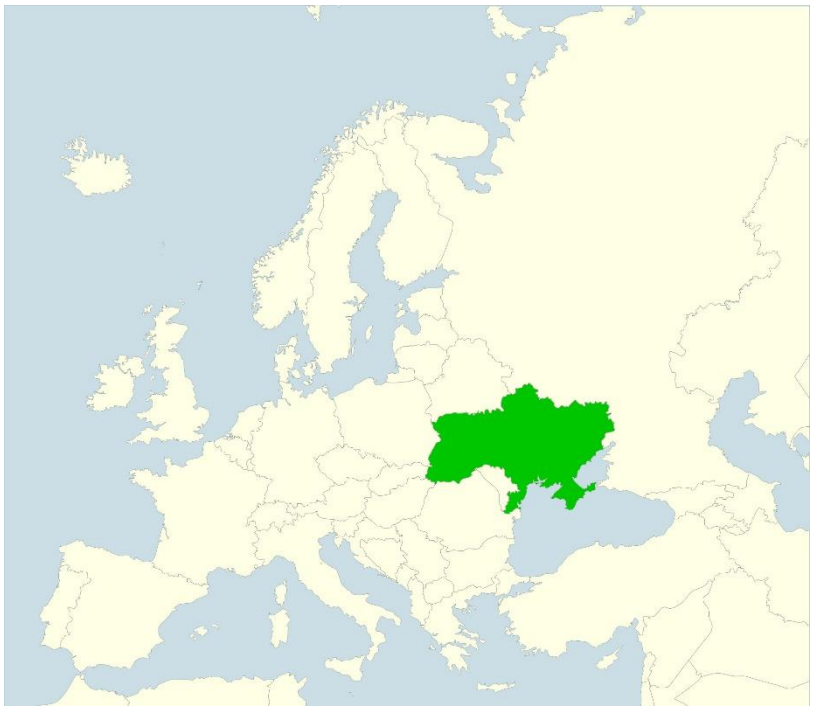

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Abstract: At each stage of the food chain, the cost of food losses differs significantly. Also, they are significantly differentiated depending on the type of products and the region, which requires different approaches to solving this problem. The purpose of our research is to assess the degree of impact of food losses and waste at each of the stages of the food chain in their total volume for a specific type of product. The empirical research was conducted using primary sources and secondary data. Primary sources were used to calculate food losses and waste according to the FAO methodology. Secondary data were used for correlation and regression analysis. According to the results of the correlation and regression analysis, the assumption of relationship absence is not confirmed, all factors are significant. It was established that the greatest impacton the volume of food losses and waste per person occurs at the stages of production and consumption, except potatoes and vegetables – the greatest impact on the amount of food losses in these groups is caused by losses at the stage of delivery and sale, at the same time food losses at the stage of handling and storage have the least impact on the performanceindicator – physical restriction of access to food. The results of this empirical study are a necessary condition for making appropriate management decisions regarding the implementation of measures to achieve SDG 2, 12 in Ukraine.

Keywords: correlation and regression analysis; food losses; food waste; food value chain; Ukraine

Анотація: На кожному етапі харчового ланцюга вартість харчових втрат істотно відрізняється. Також вони суттєво диференційовані в залежності від виду продукції та регіону, що вимагає різних підходів до вирішення даної проблеми. Метою нашого дослідження є оцінка ступеня впливу харчових втрат і відходів на кожному з етапів харчового ланцюга на їх загальний обсяг для конкретного виду продукції. Емпіричне дослідження проводилося з використанням первинних джерел і вторинних даних. Первинні джерела були використані для розрахунку харчових втрат та відходів за методологією ФАО. Для кореляційно-регресійного аналізу використовували вторинні дані. За результатами кореляційно-регресійного аналізу припущення про відсутність зв'язку не підтверджується, всі фактори є значимими. Встановлено, що найбільший вплив на кількість харчових втрат і відходів на одну людину відбувається на етапах виробництва та споживання, за винятком картоплі та овочів – найбільший вплив на кількість харчових втрат у цих групах мають втрати на етапі доставки та реалізації, при цьому втрати їжі на стадії зберігання найменше впливають на показник ефективності – фізичне обмеження доступу до їжі. Результати цього емпіричного дослідження є необхідною умовою для прийняття відповідних управлінських рішень щодо реалізації заходів щодо досягнення ЦСР 2, 12 в Україні.

Ключові слова: кореляційно-регресійний аналіз; втрати продовольства; харчові відходи; харчовий ланцюг вартості; Україна

Highlights

- In Ukraine, food losses and food waste are a defining component of the country's food potential.
- The amounts of food loss and food waste differ significantly at each stage of the food valuechain.
- The differences of food loss and food waste depend on the type of product and region.

1. Introduction

“In the former Soviet Union, Ukraine among the 15 republics was the “granary” of the state: the best chernozems; high culture, deep roots and traditions of grain cultivation; hardworking nation. In the “Treatise on Taxes and Contributions”, William Petty says that labor is the father of wealth, and land is the mother”. It is difficult not to agree with the opinion of a prominent economist. So are Ukrainians really rich and fed?” (Kotykova & Babych, 2021) The phenomenon is that no matter how much time passes, no matter how many economic reforms and political changes take place in the country, the question does not lose its relevance and remains rhetorical.

On the one hand, Ukraine ranks 20th among countries in the world in terms of the volume of exports of agricultural products in 2022 (World Trade Organization, 2023) and is one of the world leaders in the export of grain – the 5th place in the world according to the data of the 2021/2022 MR (Main agribusiness website, 2022). At the same time, the amount of arable land per capita in Ukraine is the highest among the countries of the EU and the former Soviet Union (Kotykova & Babych,2021).

On the other hand, the consumption of meat, milk, fish, fruits, berries and grapes in the countryis less than the rational norms established by the Ministry of Health of Ukraine (Babych & Kovalenko, 2018). At the same time, the share of food expenses in total population expenses significantly exceeds similar indicators in EU countries (Kotykova, Babych, Nadvynychnyy, Cherven & Shevchuk, 2021).

Why does this happen? It is especially important to find an understanding of these problems now that the country is at war. During the reconstruction processes in Ukraine, new challenges facing the agro-food system will be added to the already existing ones. Currently, the Russian Federation is not only looting Ukraine by exporting manufactured products from the temporarily occupied territories (Public. News, 2022), but the aggressor country is also resorting to terrorism and destroying all infrastructure facilities and logistics – currently, it is not even possible to estimate the damage caused; mines the territory – “the area and volumes of mining in the territory of Ukraine increased 10 times compared to the pre-war period” and makes up 30% of the country's territory (State Emergency Service of Ukraine, 2022); forcibly evacuates the population from the occupied territories, which is reported by the General Staff of the Armed Forces of Ukraine almost every day (General Staff of the Armed Forces of Ukraine, 2022), but no one knows the exact data.

The objective problem of existing imbalances in the development of the agro-food sector at theglobal level is the growth of the population with the destructive use of natural resources that ensure the physical existence of humanity. But in Ukraine, there has been negative populationgrowth for over 30 years (State Statistics Service of Ukraine. Natural Movement, 2022), with the growth of production volumes (State Statistics Service of Ukraine. Agriculture of Ukraine, 2023), so this factor does not harm the level of physical access to food products.

According to the results of earlier studies, it was established that food losses and waste are an essential component of food security in Ukraine. In particular, in 2016, the amount of food losses and waste in Ukraine was 18,366 million kcal, which is 8% of the total production (Kotykova, Babych & Pohorielova, 2020). At the same time, the specific weight of the consumption deficit, which arises as a result of food losses and waste, ranges from 25 to 72% with different types of products (Kotykova & Babych, Limitations in availability… 2019). The total amount of economic loss and lost income from food losses and waste in Ukraine amountedto 991.9 and 2224.5 million euros, respectively (Kotykova & Babych, Economic Impact… 2019).

The research on the accounting system of food losses and food waste that is based on the concept of system analysis along the entire food chain and takes into consideration the existing typology of products is critically limited in domestic science. The only comprehensive study of food losses and food waste in terms of the stages of the food value chain in Ukraine was conducted by M. M. Babych. (Babych, 2019). The calculations were based on the FAO methodology. It should be noted that domestic researchers in matters of accounting for food and food waste focus rather on certain areas of the agricultural sector, than on the stages of the food value chain.

At each stage of the food chain, the cost of food losses differs significantly. Also, they are significantly differentiated depending on the type of products and the region, which requires different approaches to solving this problem depending on the type of products, industry or sphere of the agro-food system, as well as the region.

Therefore, the research hypothesis is based on the statement that measures and policies to reduce food loss and food waste for specific types of products should be focused on different regions and stages of the food value chain. This hypothesis determines the purpose and objectives of the research.

The research focuses on the differentiation of the volume of food losses and waste between selected products and regions and along the food value chain, as well as on the contributions ofspecific stages of the food chain regarding the total volume of food losses and waste.

The realization of the set goal is expected to be achieved based on solving the following tasks.

1. To determine the loss of food and food waste:
   1.1 in terms of the main food groups: grain, potatoes, meat, milk, vegetables, fruits;
   1.2 in terms of regions of Ukraine;
   1.3 at each stage of the food value chain: production, handling and storage, processing andpackaging, distribution and market, consumption.
2. To determine the degree of influence of each of the stages of the food value chain on the total volume of food losses and waste for each type of product.
3. To determine the regions of Ukraine and the stages of the food value chain for certain typesof products, to which it is necessary to develop measures and policies to reduce foodlosses and waste.

The methodological basis of the research is the dialectical method, general scientific and specialmethods of scientific knowledge. Statistical methods were used in the research process:correlation and regression analysis, comparison of average and relative values, graphic and index methods. Program documents of state bodies of Ukraine and EU countries, methodological and statistical materials of the State Statistics Service of Ukraine, results of scientific research and international organizations served as the information base of the study.

The structural research is built as follows: a review of the scientific literature on the issues of the research; a detailed description of the research methodology and methods; presentation of results and identification of debatable issues; conclusions and prospects for further research.

2. Theoretical background

Food losses and waste is a global problem in the modern world. In the previous researches (Kotykova, Babych, Pohorielova & Shkilnyak, 2023; Kotykova, Babych & Pohorielova, 2024) we have thoroughly considered the subject of estimating the amount of food loss and waste along the food chain in different countries and regions. In this research, we focused on the factors that influence the amount of food loss and food waste, and the measures to solve this problem from the point of view of an emphasis on the role of rural areas in this process. The mentioned measures require taking into account significant differentiation, primarily, certain objective circumstances, such as: 1) distribution of food losses and waste by stages of the food chain; 2) population size; 3) possibilities of food production volumes. Thementioned factors determine the undeniable importance of the role of rural areas in the formation of food security, both at the local and global levels. At the same time, the rural area should be considered from two aspects: 1) as an entity influencing the formation of the amountof food losses and waste and 2) as an object whose development depends on the amount of foodlosses and waste.

Let's consider the mentioned factors in more detail.

1. Distribution of food losses and waste by stages of the food chain. According to the WWF report "over 15% of food is lost before leaving the farm" (WWF, 2021). The village is involvedin all stages of value

creation in the food supply chain. At the same time, the first two stages ofthe food chain (Production, Handling and storage) occur almost entirely only in rural areas, which significantly affects the quality of life of rural residents. The city also affects the formation of food losses and waste, but mainly at the last three stages of the food chain (Processing and packaging, Distribution and market, Consumption). Thus, issues of product quality, including those related to internal standards, compliance with established environmental or organic standards, ethics (especially in relation to livestock products) and several other issues are directly related to the production policy of farmers. The activity of farmers, on the one hand, depends on the decisions of the rural community in which the production is located, and on the other hand, it affects the development of the rural area.

2. Population size. As of July 2023, only in the 6 countries of the world (India – 17.8%, Pakistan – 3.0%, Bangladesh – 2.2%, Ethiopia – 1.6%, Egypt – 1.4%, Vietnam – 1.2%), the population of which is 27.2% of the entire population of the planet, more than 60% live in rural areas (Worldometer, 2023). Thereby, countries with a predominantly rural population, on the one hand, have a significant impact on the formation of global food security, and on the other hand, suffer more from food losses and waste. After all, most of the food losses and waste are formed not only at the first two stages of the food chain (Production, Handling and storage) but also at thelast two stages (Distribution and market, Consumption).

A rapid increase in the population requires an increase in the amount of food, and this inevitablymeans an even greater extensive development of agriculture. At the moment, it is difficult to say what the expansion of agricultural land will be and how it will affect the development of rural areas. Along with this, 4.4 million km^2 of agricultural land and 760 km^3 of water are already used to produce 1.2 billion tons of food waste (WWF, 2021).

3. Possibilities of food production volumes. In this context, two aspects should be considered: natural and climatic conditions and the level of economic development of the region.

There is a close relationship between natural and climatic conditions and the development of rural areas, where the production of agricultural products is concentrated. On the one hand, thedevelopment of the agricultural sector (specialization and diversification of production, the possibility of involving natural resources in the production process, etc.) almost completely depends on the natural and climatic conditions of the region. On the other hand, “Producing food uses a huge amount of land, water and energy, so wasted food significantly impacts climatechange – previous estimates suggest that food waste accounts for 8% of greenhouse gases … This is the equivalent of nearly twice the emissions produced by all the cars driven in the US and Europe in one year” (WWF, 2021).

In low-income countries, farming is the only source of income for the population, which mostlylives in rural areas and is completely dependent on natural and climatic conditions. In such regions, natural and climatic conditions affect not only the amount of agricultural products that villagers can grow but also the ability to save such products until the next harvest, that is, the volume of food losses and waste.

From the point of view of the state of the economy, agrarian countries lag far behind developedcountries that are at the post-industrial stage of development. It is logical to assume that the use of modern technologies, willingness and ability to invest in production, high level of educationof the population ensure in industrialized countries greater volumes of food production with lower food losses (Hewett, 2013; Papargyropoulou et al., 2014; Nicastro and Carillo, 2021). However, research results indicate otherwise: “Farm-stage food waste is higher in developed regions than in low-income countries across all food groups. Contrary to the widely held beliefthat farm-stage food losses are particularly acute in lower-income regions, the new data showsthat 58% of global farm-stage food waste actually occurs in middle- and high-income regions, despite their higher on-farm mechanisation, better infrastructure and more advanced agronomicpractices. One of the multiple factors behind this is agricultural overproduction and thesaturation of markets, which drives prices down and creates a structural problem that perpetuates waste” (WWF. Driven to waste …, 2021). That is, we have a scenario where a higher level of productivity leads to an increase in food loss and food waste. From the economic point of view, this effect is the result of the overproduction of products with subsequent negative consequences of the economic law of supply and demand. From a mathematical point of view, this result is explained by the increase in production

volumes, which leads to an increase in the volume of food losses and food waste, since the volume of losses is defined as a percentage of the volume of production. By the way, this, at first glance, contradiction is confirmed by the results of research by scientists whoestablished that “factors such as high gross national income per capita and high employment in agriculture are significantly associated with low food loss” (Chrisendo, D., Piipponen, J., Heino, M. et al., 2023). Therefore, rural regions in industrialized countries generate larger amounts of food losses and waste than farms in low-income countries. Such conclusions require the search for new approaches to solving the problem of reducing food losses and waste at the farm level. Of particular interest are the results of research on this issue, presented by international teams of scientists and practitioners, which contain practical recommendations of both a local (for the application of specific measures at the level of an individual farm) and global (for the application of relevant policies at the national level) nature.On January 15, 2021, the report of the participants of the "No Food Left Behind" virtual meeting, organized by the World Wildlife Fund (WWF), to develop effective and affordable measures to minimize food losses and waste, was published. The participants of the event proposed the following 5 holistic approaches to fighting food losses on the farm: 1) Food LossMeasurement Tool Implementation and Amplification; 2) Whole Crop Contracts; 3) MaximizeUtilization of Imperfect and Surplus Product Through E-Commerce; 4) Food Loss Database; 5) Mapping of Food Loss and Waste Hotspots Through the Cold Chain (WWF. 5 Holistic Approaches, 2021).

In the final report, the working group consisting of 23 members from 11 countries of the world proposed appropriate solutions for reducing food losses and waste for various participants in the process: Ideas for Operational Groups; Research needs from practice (On-Farm Food Losses: Priority Areas for Research); Other considerations (EC. EUROPE, 2020, p. 15–18). Thegroup also developed a sequence of steps for farmers to consider when formulating a strategy to reduce food losses and waste on the farm (EC.EUROPA, 2021).

When it comes to finding solutions at the national level, researchers focus mainly on three areas: (1) economic and organizational mechanisms; (2) regional features of an individual country (anexample of which is our study); (3) political decisions and programs.

Regarding the economic mechanisms for reducing food losses and waste at the farm level, certain differences are observed at the level of individual countries. Thus, researchers at the U.S. Department of Agriculture's Economic Research Service identified a variety of economicfactors that influence growers or distributors in their decisions regarding food loss, including price volatility; labor cost and availability; lack of refrigeration infrastructure; aesthetic standards and consumer preferences; quality-based contracts; various policies related to theharvest and marketing of fresh produce (Minor, Tr., Astill, G., Skorbiansky, Sh., et al., 2020). In Romania, researchers recommend that farmers focus on the following factors: labor costsand availability, consumer standards and preferences, price volatility, and supply chain factors (Stoica, D., Micu, An.-El. & Stoica, M., 2022).

Findings from studies on the causes of food losses and waste at the farm level in Indonesia identified the need for pest and disease control, human labor management during manual harvesting, and addressing gaps in appropriate harvesting technology that lead to significant crop losses (Simamora, L., Zebua, D. & Handayani, W., 2022).

The research team's recommendations for Canada's farmers include: “investing in processing infrastructure, connecting farmers with alternative markets such as “farm to school” programs,focusing on the “food as a right” paradigm, and revising policies such as the current donation tax incentives in Canada, which fail in the long term to benefit many farmers and food-insecurehouseholds” (Soma, T., Kozhikode, R. & Krishnan, R. (2021).

Given the existing objective differences between countries and individual farms, we support the thesis of scientists (O'Connor, J., Skeaff, S., Bremer, P., et al., 2023) that there are at least three economic factors influencing farmers' desire to reduce the level of food losses and wasteon the farm: 1) the cost of food losses and waste in monetary terms (Bonadonna et al., 2018); (2) food waste disposal costs compared to food loss prevention costs (Janousek et al., 2018; Thorsen et al., 2021); (3) economic sanctions arising from

the production of imperfect food fromstakeholders at other stages of the food chain (Gillman et al., 2019).

Regarding political decisions at the national level, which will contribute to the reduction of foodlosses and waste, it is worth noting at least two main ones that combine changes in the CAP policy and the new EU farm to fork strategy (Figure 1).

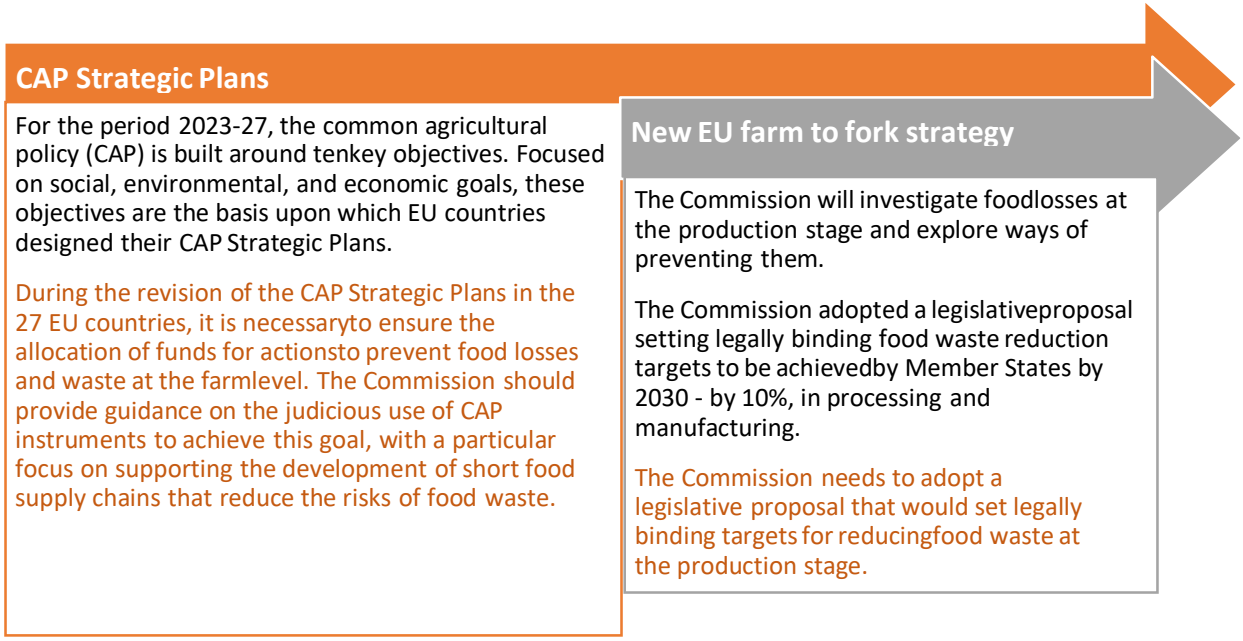

Fig 1. EU policy on solving the problem of food losses and waste at the farm level. Source: WWF. Driven to waste ..., 2021; European Commission. Food loss and waste prevention, 2023; European Commission. Farm to Fork strategy, 2023; European Commission.CAP Strategic Plans, 2023

In fact, it is practically impossible to distinguish between food losses and waste at all stages ofthe food chain at the level of rural and urban areas. But there is no need for this, since, as we have already substantiated it earlier, the impact of rural areas on the formation of the amount of food losses and waste is decisive for various factors. In addition, a peculiarity of Ukraine isthe fact that all production and the vast majority of infrastructure for the storage and processing ofproducts are concentrated in rural areas. The only exceptions are warehouses (mainly elevators)located in ports, but such products are exported – they are not processed or consumed in Ukraine. Therefore, only the last 2 stages of the food chain (Distribution and market, Consumption) apply to both rural and urban areas.

3. Methodology

Empirical research was conducted using statistical data from primary sources and secondarydata. Primary sources were used to calculate food losses and waste according to the FAOmethodology (FAO, 2011), presented in Figure 2 and Table 1.

Tab 1. Estimated waste percentages for each commodity group at each step of the FoodSupply Chain (FSC) in Europe, including Ukraine. Source: FAO (2011, p. 33–35)

Type of production	Agricultural Production	Postharvest handling and storage	Processing and packaging	Distribution: Supermarket Retail	Consumption
Cereals	2	4	0.5–10	2	25
Roots and tubers	20	9	15	7	17
Oilseeds and pulses	10	1	5	1	4
Fruits and vegetables	20	5	2	10	19
Meat	3.1	0.7	5	4	11
Fish and seafood	9.4	0.5	6	9	11
Milk	3.5	0.5	1.2	0.5	7
Meat	3.1	0.7	5	4	11
Fish and seafood	9.4	0.5	6	9	11
Milk	3.5	0.5	1.2	0.5	7

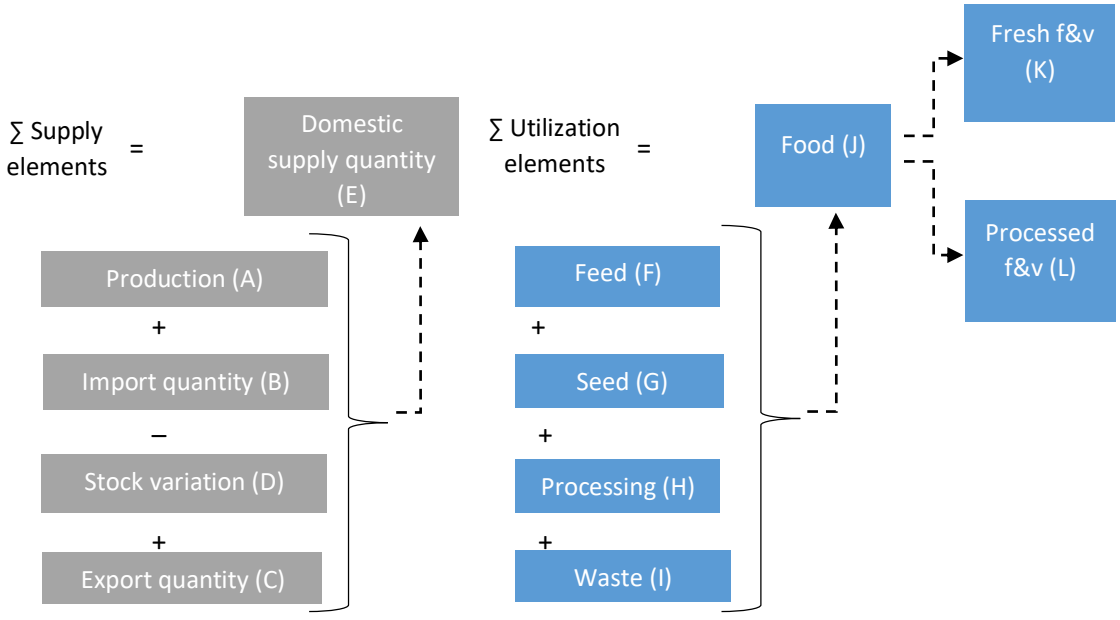

Fig 2. Methodology for accounting for food losses and food waste, developed by FAO; A+B+C-D=E-(F+G+H+I) = J= K+L. Source: FAO (2011, p. 33–35)

In our study, the terms defined in Figure 1 will be used with the following meanings:

- Production – the indicator reflects the total volumes of different types of agricultural productsin the country received during the reporting year;
- Import quantity – the indicator characterizes the number of products (in the equivalent of the primary product) that arrived from other countries by type;
- Stock variation – the indicator reflects the change in the amount of stocks of agricultural products types and derivatives of their processing (in the equivalent of the primary product) asof the end of the reporting year compared to its beginning;
- Export quantity – the indicator characterizes the number of products (in the equivalent of

the primary product) that are delivered to other countries by type;

- Feed – the indicator reflects the total volume of products used for feeding livestock both in the form of primary products and products used for the production of animal feed;
- Seed – the indicator reflects the amount of products used on all cultivated areas for the reporting year;
- Processing – the indicator reflects the amount of used products in the process of their processingto manufacture food products;
- Waste – the indicator reflects the amount of products that are lost during storage and transportation from production to the stage of sale and food consumption by the population; Fresh / Processed – the indicator reflects the amount of products that were available for food consumption by the population during the reporting year.

The main terms "food loss" and "food waste" in our research are used in the following meanings (Kotykova, Babych, Pohorielova, Shkilnyak, 2023):

- food loss – loss of food products that occurs before they reach the consumer;
- food waste – food fit for consumption which is deliberately thrown away.

The main primary source of statistical data is the State Statistics Service of Ukraine: the sections "Agriculture, forestry and fisheries", "Agriculture of Ukraine", "Natural Movement of the Population of Ukraine" on the website of the State Statistics Service of Ukraine (State Statistics Service of Ukraine, 2023) and the statistical yearbook "Balances and consumption of the main food products by population of Ukraine" (State Statistics Service of Ukraine, 2021). The statistical yearbook “Balances and consumption of the main food productsby population of Ukraine” contains information about consumption of basic food products andthe balance of food supplies.

The object of statistical observation (target population) is economic entities and households thatproduce, use and consume the main products of plant and animal husbandry within the economic territory of the country. The unit of statistical observation is a legal entity, an individual entrepreneur and a household.

According to the methodology of the State Statistics Service of Ukraine (State Statistics Service of Ukraine. Balances and consumption ..., 2021), the following are the main consumption products that make up the balance of the main agricultural products in Ukraine: Meat and meat products; Milk and milk products; Eggs; Grain and leguminous; Potatoes; Vegetables, watermelons, melons and gourds; Fruits, berries and grapes. For all the indicated groups of products, we have carried out appropriate calculations of food losses and food waste at each stage of the food value chain for each region of Ukraine. The exception was the "Eggs" group, as FAO does not provide the calculation methodology and the corresponding coefficients for food losses and food waste for this type of product. The results obtained are secondary data, which we used for correlation regression analysis. Thus, correlation and regression analysis was conducted for each of the six types of products:

- grain – grain and leguminous (including products of grain processing counted as grain);
- potatoes – potatoes (in terms of primary product);
- meat – meat and meat products (in terms of primary product), including beef and veal, pork, poultry and other types of meat;
- milk – milk and milk products (in terms of primary product);
- vegetables – vegetables, water-melons, melons and gourds (including canned and dried products counted as fresh);
- fruits – fruits, berries and grape (including canned and dried products counted as fresh). Factor signs are food losses and waste at separate stages of the food value chain:
- X_1 – food losses and waste per person at the stage of production, kg;
- X_2 – food losses and waste per person at the stage of handling and storage, kg;

- X_3 – food losses and waste per person at the stage of processing and packaging, kg;
- X_4 – food losses and waste per person at the stage of distribution and market, kg;
- X_5 – food losses and waste per person at the stage of consumption, kg.

The result of the correlation and regression analysis is food losses and waste (kg) per person (for each of the six types of products) – Y.

Correlation and regression analysis of the assessment of the factor characteristics' degree of influence on the result was carried out using Excel software. The reliability of each correlationand regression analysis result is confirmed by the following list of indicators:

- m_5, m_4, m_3, m_2, m_1, b – coefficients for variables in the correlation-regression equation;
- se_5, se_4, se_3, se_2, se_1, se_b, se_y – averages of absolute values of deviations of data points from the average;
- R^2 – coefficient of determination;
- F – Fisher's criterion calculated to assess the adequacy of the constructed model;
- Fcrit – Fisher's criterion is critical;
- df – the number of degrees of freedom;
- SSregr. – fraction of variance, which is described by the regression equation (sum ofsquares due to regression);
- SSresid. – the proportion of variance that is not taken into account when writing the equation (residual sum of squares);
- TDIST and t-statistics are standard errors (auxiliary values used to check the significanceof model coefficients).

The sample was formed based on data from 24 regions of Ukraine. Data exclude the temporarilyoccupied territory of the Autonomous Republic of Crimea, the city of Sevastopol and a part oftemporarily occupied territories in the Donetsk and Luhansk regions.

4. Results

4.1 Meat

As shown in Table 2, food losses and waste for meat vary significantly both by stages of thefood value chain and by region.

Regionally, the gap between the lowest (8.3 kg) and the highest (65.1 kg) indicator of food losses and waste for meat constitutes 56.8 kg. The three leaders with the highest rates of losseswere recorded in the Vinnytsia, Cherkasy and Kyiv regions, which specialize in the production of livestock products. The lowest level of losses was recorded in Luhansk region, which is a depressed region, and therefore the level of consumption of "expensive" calories in such regionsis low.

Tab 2. The food losses and waste of meat in Ukraine (data for correlation and regression analysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	6.5	1.4	12.2	9.2	24.5	53.9
Volyn	3.7	0.9	6.8	5.2	13.6	30.3
Dnipropetrivsk	2.4	0.5	6.4	4.9	12.9	27.1
Donetsk	0.7	0.1	3.4	2.6	6.9	13.7
Zhytomyr	1.4	0.3	3.1	2.3	6.1	13.2
Zakarpattia	1.3	0.3	2.9	2.1	5.7	12.3
Zaporizhzhia	1.0	0.2	3.5	2.6	7.0	14.4
Ivano-Frankivsk	1.9	0.4	3.8	2.9	7.7	16.7
Kyiv	3.7	0.8	12.9	9.8	25.9	53.0
Kirovohrad	1.8	0.4	3.9	3.0	7.8	16.8
Luhansk	0.3	0.0	2.1	1.6	4.2	8.3
Lviv	1.5	0.4	4.3	3.2	8.6	18.0
Mykolaiv	0.9	0.2	2.7	2.0	5.3	11.0
Odesa	0.6	0.1	2.6	2.0	5.2	10.5
Poltava	1.8	0.4	4.6	3.5	9.2	19.4
Rivne	1.5	0.3	3.5	2.7	7.1	15.1
Sumy	1.4	0.3	3.3	2.4	6.4	13.8
Ternopil	1.6	0.4	4.1	3.1	8.2	17.4
Kharkiv	1.1	0.3	3.6	2.7	7.1	14.7
Kherson	1.2	0.3	3.4	2.7	6.9	14.5
Khmelnytsky	1.6	0.4	3.9	3.0	7.7	16.5
Cherkasy	8.4	1.9	14.5	11.0	29.2	65.1
Chernivtsi	1.4	0.3	3.5	2.6	7.0	15.0
Chernihiv	1.1	0.2	3.5	2.6	7.0	14.4
Ukraine (reference data)	1.9	0.4	4.9	3.7	9.8	20.6

In the breakdown of the food value chain stages, the gap between the highest and lowest indicators is as follows: at the production stage – 8.1 kg, at the handling and storage stage – 1.9 kg, at the processing and packaging stage – 12.4 kg, at the delivery and sale stage – 9.4 kg, at the consumption stage – 25.0 kg. The gap between the highest and lowest indicators of food losses and waste by meat in the across stages of the food value chain by region is presented in Figure 3.

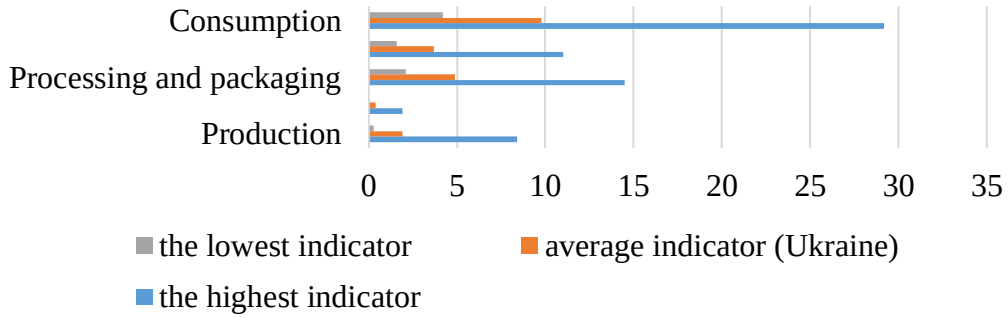

Fig 3. The gap between the highest and lowest indicators of food losses and waste by meat in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste formeat, given in Table 3, the assumption of relationship absence is not confirmed, all factors aresignificant. The obtained data indicate that the lowest impact on the level of food losses and waste in meat is at the stage of handling and storage, and the highest at the stage of consumption.

Tab 3. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages in the food value chain in Ukraine for meat. Source: calculated by the authors

m_5, m_4, m_3, m_2, m_1, b	1.2979	0.5973	0.6912	0.3861	1.1619	0.0165
se_5, se_4, se_3, se_2, se_1, se_b	0.198603	0.421113	0.346130	0.480546	0.111176	0.018123
R^2, se_y	0.999994	0.039172				
F, df	665892.31	18				
SS regr., SS resid.	5108.812	0.028				
$У=1.1619x_1 + 0.3861x_2 + 0.6912x_3 + 0.5973x_4 + 1.2979x_5 + 0.0165$						
F, Fcrit.	665892.31	2.93	the assumption of relationship absence is not confirmed			
t-statistics	6.535133	1.418432	1.996862	0.803516	10.450784	0.908880
TDIST	0.000002	0.086573	0.030595	0.216080	0.000000	0.187711
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

4.2 Milk

As shown in Table 4, food losses and waste in milk vary significantly both by stages of the foodvalue chain and by region.

Tab 4. The food losses and waste of milk in Ukraine (data for correlation and regressionanalysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	19.5	2.7	7.5	3.1	43.1	75.9
Volyn	14.4	2.0	4.2	1.7	24.3	46.6
Dnipropetrivsk	3.6	0.5	3.2	1.3	18.6	27.1
Donetsk	1.6	0.2	2.4	1.0	13.8	19.0
Zhytomyr	16.6	2.3	5.7	2.3	33.1	60.0
Zakarpattia	9.2	1.3	2.9	1.2	17.1	31.8
Zaporizhzhia	5.4	0.7	3.3	1.4	19.0	29.8
Ivano-Frankivsk	12.2	1.7	4.1	1.7	23.9	43.7
Kyiv	9.2	1.3	9.1	3.8	53.2	76.5
Kirovohrad	11.6	1.6	4.8	2.0	27.4	47.3
Luhansk	2.0	0.3	2.1	0.9	12.6	17.9
Lviv	7.8	1.1	3.4	1.5	20.1	33.9
Mykolaiv	10.8	1.5	5.0	2.1	29.0	48.4
Odesa	5.5	0.8	2.9	1.2	17.2	27.7
Poltava	20.3	2.8	8.1	3.4	46.6	81.0
Rivne	13.7	1.9	4.1	1.7	23.9	45.3
Sumy	13.6	1.9	5.7	2.4	33.2	56.8
Ternopil	15.5	2.2	5.4	2.3	31.3	56.6
Kharkiv	7.1	1.0	4.7	2.0	27.5	42.4
Kherson	10.1	1.4	4.5	1.9	26.3	44.3
Khmelnytsky	16.6	2.3	5.7	2.3	33.1	60.1
Cherkasy	15.3	2.1	7.0	2.9	40.3	67.6
Chernivtsi	11.5	1.5	3.9	1.5	22.2	40.6
Chernihiv	19.3	2.6	7.3	3.0	41.7	73.9
Ukraine (reference data)	9.5	1.3	4.5	1.9	26.1	43.3

Regionally, the gap between the lowest (8.3 kg) and the highest (65.1 kg) rate of food losses and waste in milk is 56.8 kg. The three leaders with the highest rates of losses were recorded inthe Vinnytsia, Poltava and Kyiv regions. As was noted earlier, this situation is connected with the specializations of regions. The lowest level of losses was recorded in Luhansk regions, forthe same reasons as for meat consumption.

In the breakdown of the stages of the food value chain, the gap between the highest and lowestindicators is as follows: at the production stage – 18.3 kg, at the handling and storage stage – 2.5kg, at the processing and packaging stage – 7.0 kg, at the delivery and sale stage – 2.9 kg, at theconsumption stage – 40.6 kg. The gap between the highest and lowest indicators of food lossesand waste by milk in the across stages of the food value chain by region is presented in Figure 4.

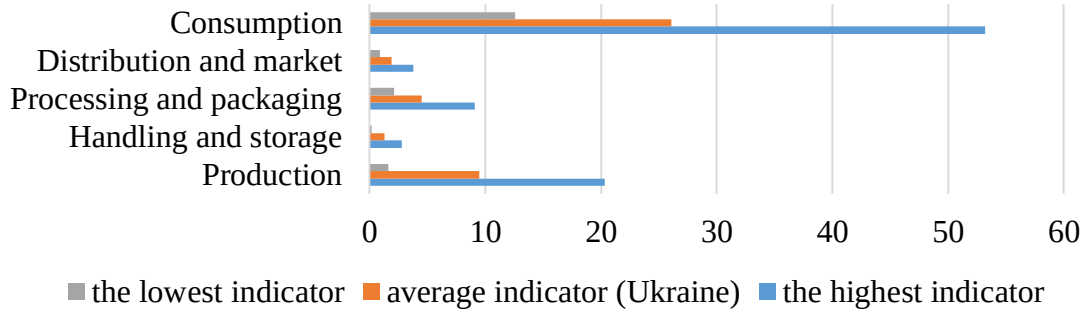

Fig 4. The gap between the highest and lowest indicators of food losses and waste by milk in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste in milk, given in Table 5, the assumption of relationship absence is not confirmed, all factors aresignificant. The obtained data show that the lowest impact on the level of food losses and wastein milk is at the stage of handling and storage, and the highest is almost equal – at the stages ofproduction and consumption.

Tab 5. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages in the food value chain in Ukraine for milk. Source: calculated by the authors

m_5, m_4, m_3, m_2, m_1, b	1.1533	0.6050	0.2733	-0.0831	1.1526	-0.0276
se_5, se_4, se_3, se_2, se_1, se_b	0.0880	0.5811	0.5347	0.5419	0.0755	0.0355
R^2, se_y	0.999993	0.055726				
F, df	495443.34	18				
SS regr., SS resid.	7692.782	0.056				
$y=1.1526x_1 - 0.0831x_2 + 0.2733x_3 + 0.605x_4 + 1.1533x_5 - 0.0276$						
F, Fcrit.	495443.34	2.93	the assumption of relationship absence is not confirmed			
t-statistics	13.103336	1.041198	0.511165	0.153422	15.261161	0.775987
TDIST	0.000000	0.155784	0.307724	0.439886	0.000000	0.223917
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

4.3 Grain

As shown by the data in Table 6, food losses and waste by grain vary significantly both by thestages of the food value chain and by region.

Tab 6. The food losses and waste of grain in Ukraine (data for correlation and regressionanalysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	20.9	4.1	78.3	6.6	80.6	190.5
Volyn	4.5	0.9	19.9	1.6	20.5	47.4
Dnipropetrivsk	4.9	1.0	2.8	0.2	2.8	11.7
Donetsk	2.2	0.4	4.0	0.3	4.1	11.0
Zhytomyr	10.4	2.0	45.2	3.8	46.5	107.9
Zakarpattia	0.9	0.2	5.4	0.5	5.5	12.4
Zaporizhzhia	8.0	1.6	15.1	1.3	15.5	41.4
Ivano-Frankivsk	2.5	0.5	10.9	0.9	11.2	25.9
Kyiv	12.2	2.4	45.0	3.8	46.4	109.8
Kirovohrad	22.1	4.3	87.3	7.4	89.8	210.7
Luhansk	3.4	0.6	5.0	0.4	5.1	14.6
Lviv	2.7	0.6	11.8	1.0	12.1	28.2
Mykolaiv	11.7	2.3	17.8	1.5	18.3	51.7
Odesa	9.9	1.9	15.0	1.3	15.4	43.5
Poltava	23.9	4.7	99.0	8.3	101.9	237.9
Rivne	5.4	1.0	11.5	0.9	11.9	30.8
Sumy	23.2	4.5	81.9	6.9	84.3	200.7
Ternopil	12.9	2.5	31.0	2.6	31.8	80.8
Kharkiv	8.0	1.6	12.4	1.0	12.8	35.8
Kherson	9.4	1.8	13.5	1.1	13.8	39.7
Khmelnytsky	14.9	3.0	61.3	5.1	63.1	147.5
Cherkasy	21.0	4.1	66.3	5.6	68.2	165.1
Chernivtsi	1.4	0.3	1.1	0.1	1.1	4.1
Chernihiv	24.7	4.8	25.8	2.1	26.6	84.2
Ukraine (reference data)	9.4	1.8	25.1	2.1	25.8	64.3

Regionally, the gap between the lowest (4.1 kg) and the highest (237.9 kg) indicator of food losses and waste by grain is 233.8 kg. The three leaders with the highest rates of losses recordedare the Kirovohrad, Poltava, and Sumy regions, which have concentrated technical capacity forgrain processing. The lowest level of losses was recorded in the Chernivtsi region, which is related to the specialization of the region.

In terms of the stages of the food value chain, the gap between the highest and lowest indicatorsis as follows: at the production stage – 22.5 kg, at the handling and storage stage – 4.4 kg, at theprocessing and packaging stage – 97.9 kg, at the delivery and sale stage – 8.2 kg, at the consumption stage – 100.8 kg. The gap between the highest and lowest indicators of food lossesand waste by grain in the across stages of the food value chain by region is presented in Figure 5.

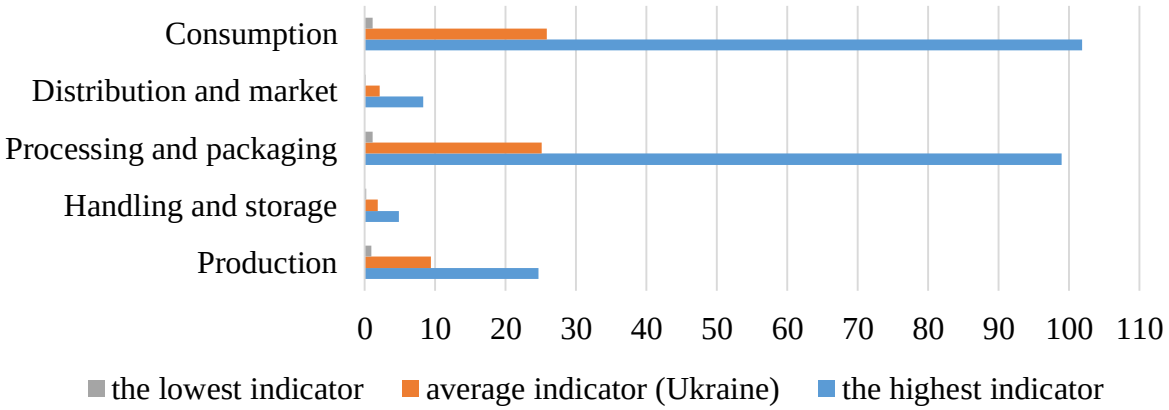

Fig 5. The gap between the highest and lowest indicators of food losses and waste by grain in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste by grain, given in Table 7, the assumption of relationship absence is not confirmed, all factors aresignificant. The obtained data show that the lowest impact on the level of food losses and wastein grain is at the stage of processing and packaging, and the highest at the stage of consumption.

Tab 7. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages in the food value chain in Ukraine for grain. Source: calculated by the authors

m_5, m_4, m_3, m_2, m_1, b	1.9014	0.4476	0.1182	0.5773	1.0825	0.0379
se_5, se_4, se_3, se_2, se_1, se_b	0.5494	0.6877	0.5893	0.5242	0.1028	0.0235
R^2, se_y	0.9999995	0.056775				
F, df	7606690.03	18				
SS regr., SS resid.	122597.102	0.058				
$y=1.0825x_1 + 0.5773x_2 + 0.1182x_3 + 0.4476x_4 + 1.9014x_5 + 0.0379$						
F, Fcrit.	7606690.03	2.93	the assumption of relationship absence is not confirmed			
t-statistics	3.460997	0.650877	0.200528	1.101300	10.529802	1.614041
TDIST	0.001394	0.261674	0.421658	0.142638	0.000000	0.061956
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

4.4 Potatoes

As shown in Table 8, food losses and waste from potatoes vary significantly both by stages ofthe food value chain and by region.

Regionally, the gap between the lowest (36.4 kg) and the highest (291.3 kg) rate of food lossesand waste for potatoes is 254.9 kg. The three leaders with the highest rates of losses are the Kyiv, Vinnytsia and Zhytomyr regions, which specialize in the production of potatoes. The lowest level of losses was recorded in the Donetsk region, which is related to the specialization of the region.

Tab 8. The food losses and waste of potatoes in Ukraine (data for correlation and regressionanalysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	101.7	3.6	57.1	22.6	51.2	236.3
Volyn	95.2	3.5	36.0	14.3	32.3	181.2
Dnipropetrivsk	16.3	0.6	17.3	6.8	15.5	56.5
Donetsk	8.4	0.3	12.1	4.8	10.8	36.4
Zhytomyr	92.9	3.3	58.4	23.1	52.3	230.1
Zakarpattia	37.2	1.4	19.5	7.8	17.6	83.3
Zaporizhzhia	13.3	0.5	14.7	5.8	13.2	47.4
Ivano-Frankivsk	61.8	2.2	33.3	13.2	29.9	140.4
Kyiv	85.9	3.1	88.3	35.0	79.0	291.3
Kirovohrad	54.7	2.0	46.5	18.4	41.6	163.3
Luhansk	10.1	0.4	15.3	6.1	13.7	45.5
Lviv	55.9	2.0	26.3	10.4	23.6	118.2
Mykolaiv	20.4	0.7	21.0	8.3	18.8	69.3
Odesa	19.8	0.7	16.2	6.4	14.5	57.7
Poltava	65.3	2.4	23.7	9.4	21.2	122.0
Rivne	94.0	3.4	37.8	15.0	33.9	184.0
Sumy	84.4	3.1	51.5	20.5	46.2	205.7
Ternopil	81.6	2.9	35.8	14.2	32.1	166.5
Kharkiv	34.9	1.3	23.5	9.3	21.0	90.0
Kherson	23.2	0.9	20.7	8.1	18.5	71.3
Khmelnytsky	89.9	3.3	39.1	15.5	35.1	182.8
Cherkasy	59.6	2.1	36.3	14.4	32.5	145.0
Chernivtsi	57.3	2.1	33.7	13.3	30.2	136.5
Chernihiv	101.8	3.7	17.5	7.0	15.7	145.5
Ukraine (reference data)	48.0	1.7	29.4	11.7	26.3	117.1

In the breakdown of the stages of the food value chain, the gap between the highest and lowest indicators is as follows: at the production stage – 93.3 kg, at the handling and storage stage – 3.0 kg, at the processing and packaging stage – 76.2 kg, at the delivery and sale stage – 30.2 kg, at the consumption stage – 68.2 kg. The gap between the highest and lowest indicators of food losses and waste by potatoes in the across stages of the food value chain by region is presented in Figure 6.

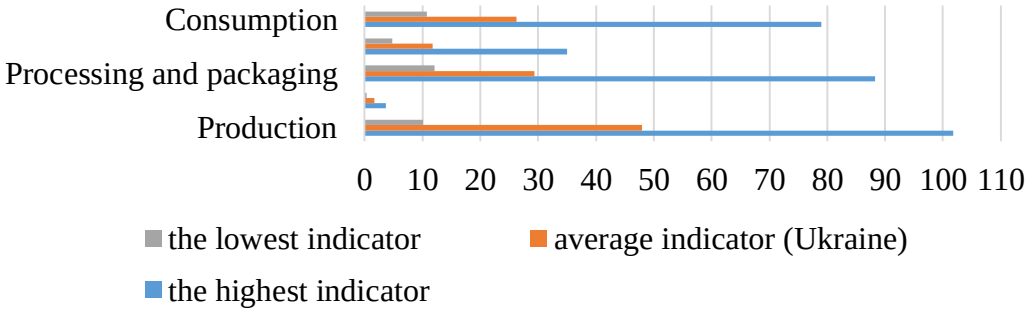

Fig 6. The gap between the highest and lowest indicators of food losses and waste by potatoes in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste by grain, given in Table 9, the assumption of relationship absence is not confirmed, all factors are significant. The obtained data show that the lowest impact on the level of food losses and wastefor potatoes is at the stage of handling and storage, and the highest at the stage of delivery and sale.

Tab 9. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages in the food value chain in Ukraine for potatoes. Source: calculated by the authors

m_5, m_4, m_3, m_2, m_1, b	1.0776	1.3320	0.8013	-0.3364	1.0468	0.0036
se_5, se_4, se_3, se_2, se_1, se_b	0.5410	0.5278	0.4705	0.5335	0.0193	0.0269
R^2, se_y	0.999999	0.058784				
F, df	6285913.56	18				
SS regr., SS resid.	108608.116	0.062				
$У=1.0468x_1 - 0.3364x_2 + 0.8013x_3 + 1.332x_4 + 1.0776x_5 + 0.0036$						
F, Fcrit.	6285913.56	2.93	the assumption of relationship absence is not confirmed			
t-statistics	1.992037	2.523569	1.703124	0.630510	54.227706	0.135104
TDIST	0.030880	0.010620	0.052875	0.268142	0.000000	0.447014
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

4.5 Vegetables

As shown by the data in Table 10, food losses and waste on vegetables vary significantly bothby stages of the food value chain and by region.

Tab 10. The food losses and waste of vegetables in Ukraine (data for correlation andregression analysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	27.9	0.6	3.4	22.6	38.7	93.1
Volyn	24.3	0.5	2.8	19.0	32.5	79.1
Dnipropetrivsk	20.7	0.4	2.3	16.9	28.8	69.1
Donetsk	4.7	0.1	1.5	12.0	20.5	38.8
Zhytomyr	21.1	0.4	2.5	18.4	31.4	73.8
Zakarpattia	18.6	0.4	2.2	16.2	27.6	65.0
Zaporizhzhia	22.0	0.5	3.0	19.5	33.3	78.2
Ivano-Frankivsk	10.9	0.2	1.7	12.5	21.4	46.7
Kyiv	32.3	0.6	5.2	41.2	70.3	149.7
Kirovohrad	23.2	0.4	2.7	18.9	32.3	77.7
Luhansk	7.2	0.1	1.1	9.2	15.9	33.6
Lviv	17.4	0.4	2.4	17.2	29.4	66.7
Mykolaiv	40.2	0.8	5.8	35.0	59.9	141.8
Odesa	14.0	0.3	2.3	15.8	27.1	59.4
Poltava	33.5	0.7	3.9	25.0	42.7	105.7
Rivne	17.8	0.3	2.2	15.4	26.4	62.2
Sumy	16.5	0.4	1.8	14.2	24.4	57.2
Ternopil	21.4	0.5	2.6	18.1	31.1	73.6
Kharkiv	24.6	0.5	2.6	18.7	31.9	78.3
Kherson	124.7	2.5	15.8	83.6	143.0	369.4
Khmelnytsky	15.6	0.3	1.6	13.7	23.5	54.8
Cherkasy	26.2	0.5	3.1	20.9	35.7	86.3
Chernivtsi	22.9	0.4	3.1	21.3	36.3	83.9
Chernihiv	16.3	0.3	2.0	15.5	26.4	60.6
Ukraine (reference data)	22.1	0.4	2.9	20.0	34.2	79.6

Regionally, the gap between the lowest (33.6 kg) and the highest (369.4 kg) indicator of food losses and waste for vegetables is 335.8 kg. Kherson region is the undisputed and sole leader in the production of vegetables in Ukraine, so this region has the highest indicators of food losses and waste in vegetables. Compared to other regions, indicators of food losses and waste related to vegetables are significantly higher in Kyiv and Mykolaiv regions, which produce andprocess a significant amount of vegetables in Ukraine. The lowest level of losses was recordedin the Luhansk region, which is a depressed region, and therefore the level of consumption of "expensive" calories in such regions is low.

In terms of the stages of the food value chain, the gap between the highest and lowest indicatorsis as follows: at the production stage – 120.0 kg, at the handling and storage stage – 2.4 kg, at the processing and packaging stage – 14.7 kg, at the delivery and sale stage – 74.6 kg, at the consumption stage – 127.1 kg. The gap between the highest and lowest indicators of food lossesand waste by vegetables in the across stages of the food value chain by region is presented in Figure 7.

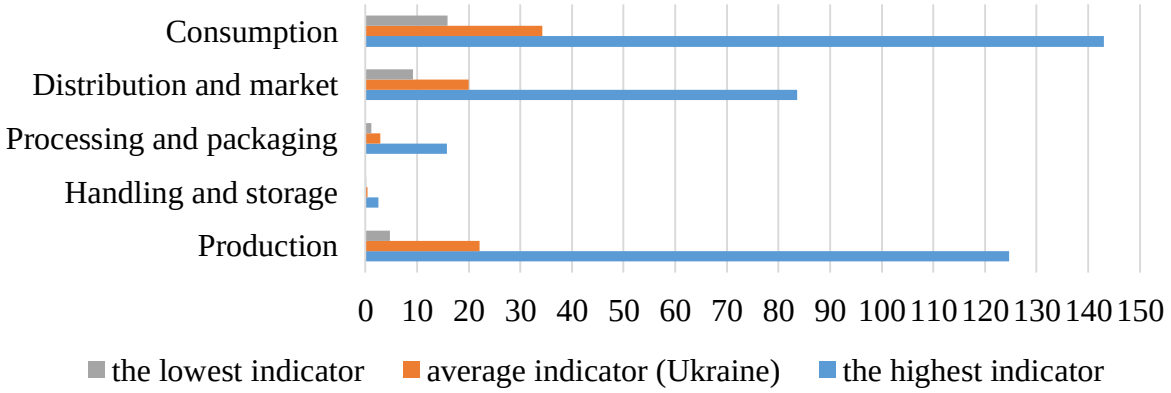

Fig 7. The gap between the highest and lowest indicators of food losses and waste by vegetables in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste on vegetables, given in Table 11, the assumption of relationship absence is not confirmed, all factors are significant. The obtained data show that the lowest impact on the level of food lossesand waste for vegetables is at the stage of handling and storage, and the highest at the stage of delivery and sale.

Tab 11. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages i the food value chain in Ukraine for vegetables. Source: calculated by the author

m_5, m_4, m_3, m_2, m_1, b	0.8969	1.1778	0.9768	-0.6871	1.0347	0.0238
se_5, se_4, se_3, se_2, se_1, se_b	0.2801	0.4771	0.0567	0.6055	0.0127	0.0397
R^2, se_y	0.999999	0.060264				
F, df	5492611.45	18				
SS regr., SS resid.	99739.264	0.065				
$У=1.0347x_1 - 0.6871x_2 + 0.9768x_3 + 1.1778x_4 + 0.8969x_5 + 0.0238$						
F, Fcrit.	5492611.45	2.93	the assumption of relationship absence is not confirmed			
t-statistics	3.201848	2.468875	17.230689	1.134666	81.476812	0.598695
TDIST	0.002471	0.011898	0.000000	0.135700	0.000000	0.278418
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

4.6 Fruits

As shown by the data in Table 12, food losses and waste on fruits vary significantly both bystages of the food value chain and by regions.

Tab 12. The food losses and waste of fruits in Ukraine (data for correlation and regressionanalysis). Source: calculated by the authors according to the FAO methodology based on data from the State Statistics Service of Ukraine (2021)

Region	X_1	X_2	X_3	X_4	X_5	Y
Vinnytsia	15.0	0.3	2.5	14.0	24.0	55.8
Volyn	3.2	0.1	0.7	4.7	8.1	16.6
Dnipropetrivsk	4.2	0.1	0.7	5.3	9.1	19.5
Donetsk	1.9	0.0	0.4	2.9	4.9	10.1
Zhytomyr	3.0	0.1	0.6	4.0	6.9	14.5
Zakarpattia	10.6	0.2	1.7	9.2	15.8	37.7
Zaporizhzhia	3.4	0.1	0.7	5.1	8.7	18.0
Ivano-Frankivsk	3.1	0.1	0.7	4.6	7.9	16.3
Kyiv	3.6	0.1	2.4	18.1	31.0	55.2
Kirovohrad	2.8	0.1	0.6	4.7	7.9	16.0
Luhansk	1.1	0.0	0.4	3.0	5.0	9.5
Lviv	3.7	0.1	0.6	4.7	7.9	17.0
Mykolaiv	6.7	0.2	1.5	8.8	15.0	32.0
Odesa	11.6	0.3	2.2	12.4	21.2	47.6
Poltava	4.8	0.1	0.8	5.2	8.9	19.8
Rivne	5.8	0.1	0.8	4.7	8.1	19.6
Sumy	1.3	0.0	0.4	3.0	5.1	9.6
Ternopil	6.0	0.1	0.9	6.3	10.9	24.4
Kharkiv	2.6	0.0	0.8	5.5	9.4	18.3
Kherson	7.6	0.2	1.5	8.8	15.2	33.2
Khmelnytsky	13.7	0.3	1.9	11.5	19.7	47.1
Cherkasy	3.7	0.1	0.9	5.8	9.9	20.3
Chernivtsi	18.4	0.3	2.9	16.7	28.7	67.2
Chernihiv	1.3	0.0	0.4	2.8	4.8	9.3
Ukraine (reference data)	5.3	0.1	1.0	6.8	11.6	24.8

Regionally, the gap between the lowest (9.3 kg) and the highest (67.2 kg) indicators of food losses and waste for fruits is 57.9 kg. The three leaders with the highest rates of loss are the Chernivtsi and Vinnytsia regions, which specialize in fruit production, as well as Kyiv region,which is characterized by a high level of fruit consumption due to the high level of income of the region's population. Almost the same low level of losses was recorded in the Luhansk, Donetsk, Sumy and Chernihiv regions, which is related to both the lack of production in these regions and the very low level of fruit consumption by the population in these regions.

In terms of the stages of the food value chain, the gap between the highest and lowest indicators is as follows: at the production stage – 15.8 kg, at the handling and storage stage – 0.3 kg, at theprocessing and packaging stage – 2.5 kg, at the delivery and sale stage – 15.3 kg, at the consumption stage – 26.2 kg. The gap between the highest and lowest indicators of food lossesand waste by fruits in the across stages of the food value chain by region is presented in Figure 8.

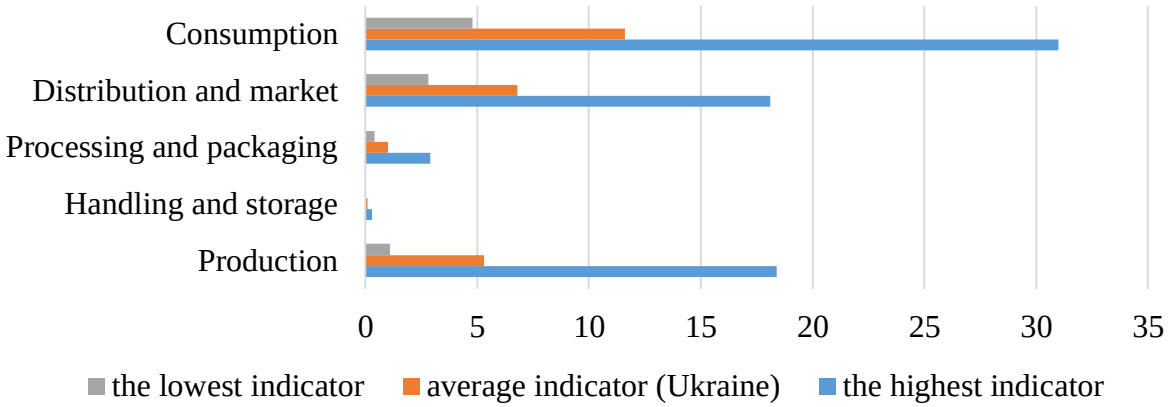

Fig 8. The gap between the highest and lowest indicators of food losses and waste by fruits in the across stages of the food value chain by region. Source: calculated and developed by the authors

According to the results of the correlation and regression analysis of food losses and waste by fruit, given in Table 13, the assumption of relationship absence is not confirmed, all factors are significant. The obtained data show that the lowest impact on the level of food losses and wastein fruits is at the stage of handling and storage, and the highest at the stage of consumption.

Tab 13. The results of the correlation and regression analysis of the assessment of the food losses and waste impact by stages in the food value chain in Ukraine for fruits. Source: calculated by the authors

m_5, m_4, m_3, m_2, m_1, b	1.1684	0.7185	0.9454	-0.6250	1.0415	-0.0339
se_5, se_4, se_3, se_2, se_1, se_b	0.2641	0.4497	0.2149	0.5116	0.0125	0.0294
R^2, se_y	0.999991	0.056840				
F, df	397329.55	18				
SS regr., SS resid.	6418.480	0.058				
$y=1.0415x_1 - 0.625x_2 + 0.9454x_3 + 0.7185x_4 + 1.1684x_5 - 0.0339$						
F, Fcrit.	397329.55	2.93	the assumption of relationship absence is not confirmed			
t-statistics	4.423144	1.597652	4.400233	1.221771	83.494059	1.152922
TDIST	0.000164	0.063763	0.000173	0.118777	0.000000	0.132012
Comparison of evaluation	effective feature	effective feature	effective feature	effective feature	effective feature	

5. Discussion

Mainly, in the issues of assessment of food losses and waste, discussions are caused by the methodology, the content of the indicators used in the calculations, as well as the information support of loss accounting. In our study, we use the methodology for calculating food losses and waste, proposed by FAO, because we believe that it best satisfies the outlined discussion questions.

Firstly, the FAO methodology is based on the balance method of calculation, which is fully consistent with the balance method used by the State Statistics Service of Ukraine when compiling food balances in Ukraine.

Secondly, the essence of the indicators used in the calculations has the same content load and method of calculation. Thus, the State Statistics Service of Ukraine, together with VoxUkraine, with the support of the UN Development Program in Ukraine based on the Voluntary National Review of the Sustainable Development Goals, annually assesses the progress of achieving the Sustainable Development Goals according to the methodology of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP, 2023).The list of national indicators of sustainable development goals, for which the calculation is carried out according to the methodology of the Economic and Social Commission for Asia

and the Pacific Ocean (UNESCAP), and which are approved by the order of the Cabinet of Ministers of Ukraine dated August 21, 2019 No. 686-r "Issues of data collection for monitoring the implementation of the goals of sustainable development" (Cabinet of Ministers of Ukraine, 2019).

Thirdly, information support both at the level of FAO and at the level of the State Statistics Service allows for appropriate calculations both at the national and international levels.

However, there are issues that require empirical confirmation and agreement in the future. Weare talking about the need to adjust weight percentages of food losses and waste (as a percentageof what is included at each stage. For example, the amount of grain loss at the stages of production and handling and storage is only 2 and 4%, respectively, but for Ukraine, such indicators are understated. This is since Ukraine belongs to the "Europe"group, but the technologies of production, storage and processing of products in Ukraine are significantly different from those used in the EU. In addition to this, certain types of products in Ukraine are almost entirely produced by households. It should be explained that householdscannot be equated with farms and, even more so, with enterprises, which manage ten times more resources for operating than households. Thus, according to the State Statistics Service ofUkraine (State Statistics Service of Ukraine. Agriculture of Ukraine, 2023), from 2000 to 2021,households produced more than 50% of agricultural products, in particular: potatoes – from 97to 98%; vegetables – from 83 to 86%; fruits – from 79 to 88%; eggs – from 40 to 66%; wool from 61 to 91%; honey – from 93 to 99%. With a high degree of probability, we can assume that such farms, due to the low technological level and the lack of investment opportunities at the stages of production and handling and storage, lose a significantly larger amount of productsthan in the EU, where the same products are produced by high-tech farms, which have significant financial support from the state. On the other hand, 25% of grain losses at the stageof consumption is too high for Ukraine. Ukrainians are traditionally very careful about food. The historical memory of the Great Famine of the 1930s does not allow Ukrainians to throw away food irresponsibly. Almost all food will be processed by the family in one way or anotheruntil it is all consumed. Therefore, certain weighting coefficients are overestimated, and othersare, on the contrary, underestimated for Ukraine. Thus, in general, we believe that the obtainedoverall averaged results are sufficiently relevant.

Another issue is the information provision of individual indicators regarding their presentationby specific countries in the full-time dimension. Not all indicators on the FAO platform are equally represented by all countries, often some indicators are missing for a certain time interval. It is important to eliminate such problems for the possibility of conducting correct international comparisons or determining development trends. Thus, in our study, we did not calculate the losses of fish and seafood, which are in the list proposed by the FAO, because thenational database of the State Statistics Service of Ukraine does not keep records of data on theindicated products in the amount sufficient to carry out the relevant calculations. Instead, in our study, we calculated food losses and waste for fruits and vegetables separately, whereas FAO combines these types of products. Such minor differences may occur because countries have their own specifications and specialization of production. Thus, few regions in Ukraine are engaged in fish production, but fruits and vegetables are produced in the vast majority of regionsof Ukraine.

Therefore, the use of the FAO methodology for calculating food losses and waste in Ukraine using the primary data of the State Statistics Service of Ukraine is appropriate, and the results obtained in this way are relevant and reliable.

According to the results of the correlation and regression analysis shown in tables 3, 5, 7, 9, 11 and 13, the assumption of relationship absence is not confirmed, all factors are significant.

Individual TDIST values > 5%. A significant deviation is observed in the case when there are significant gaps between indicators in one studied group. For example, the deviation between the lowest and the highest value of food loss and food waste for milk at the storage stage is 1:9. But it is precisely these gaps that point to regional peculiarities.

In the scientific environment of Ukraine, the prevailing opinion is that the solution to the problem of food security is in the area of increasing the volume of production (Berehovyi, 2015; *Bokiy,* 2018; Horokh, Ostapenko, Tykhyi, 2023; Kovalenko, Yashchenko, 2022; Moroz, Verbytskyi, Kuts, Mytchenok, 2023; Mostova, 2019; *Sychevskyi, Romanchuk, 2019*). However, our results prove that food loss and food waste

are significant at all stages of the food value chain. The gap between the highest and lowest indicatorsis as follows (Figure 9): at the production stage – 14.8 (111.9 kg), at the handling and handlingand storage stage – 14.7 (4.1 kg), at the processing and packaging stage – 39.2 (94.5 kg), at thestage of delivery and sale – 25.7 (71.7 kg), at the stage of consumption – 5.1 (102.1 kg).

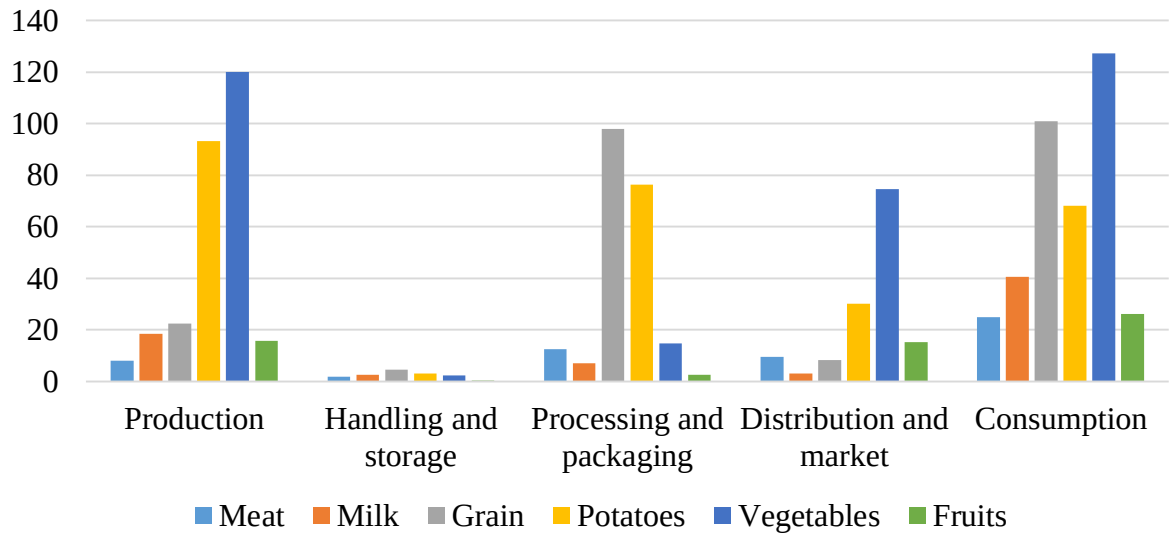

Fig 9. The gap between the highest and lowest rates of food losses and waste per person at different stages of the food value chain, kg. Source: calculated and by the authors

Significant differences in food losses and food waste were also found in the regions of Ukraine. In terms of regions, the gap between the highest and lowest indicators of food losses and waste is large: for meat – 7.5 (56.8 kg), for milk – 7.8 (56.8 kg), for grain – 58.0 (233.8 kg), for potatoes – 8.0 (254.9 kg), for vegetables – 11.0 (335.8 kg), for fruits – 7.2(57.9 kg).

The obtained results allow us to state that measures and policies to reduce food losses and wastefor specific types of products should be focused on different regions and stages of the food value chain (Figure 10): for meat – Vinnytsia, Cherkasy, Kyiv regions, stage – consumption; for milk – Vinnytsia, Poltava, Kyiv regions, stages – production and consumption; by grain – Kirovohrad, Poltava, Sumy regions, stage – consumption; for potatoes – Vinnytsia, Zhytomyr, Kyiv regions, stage – distribution and market; for vegetables – Kherson, Mykolaiv, Kyiv regions, stage – distribution and market; by fruit – Vinnytsia, Chernivtsi, Kyiv regions, stage –consumption.

The fact that specialization in the production of a certain type of product means high losses of food and food waste at this stage is typical for all regions. Significant volumes of production, in turn, stimulate the growth of demand, and therefore – an increase in food losses and waste atthe stage of consumption. Therefore, it should be understood that the strategy of increasing production volumes is not a guarantee of the stability of the food system, as politicians and scientists in Ukraine often emphasize.

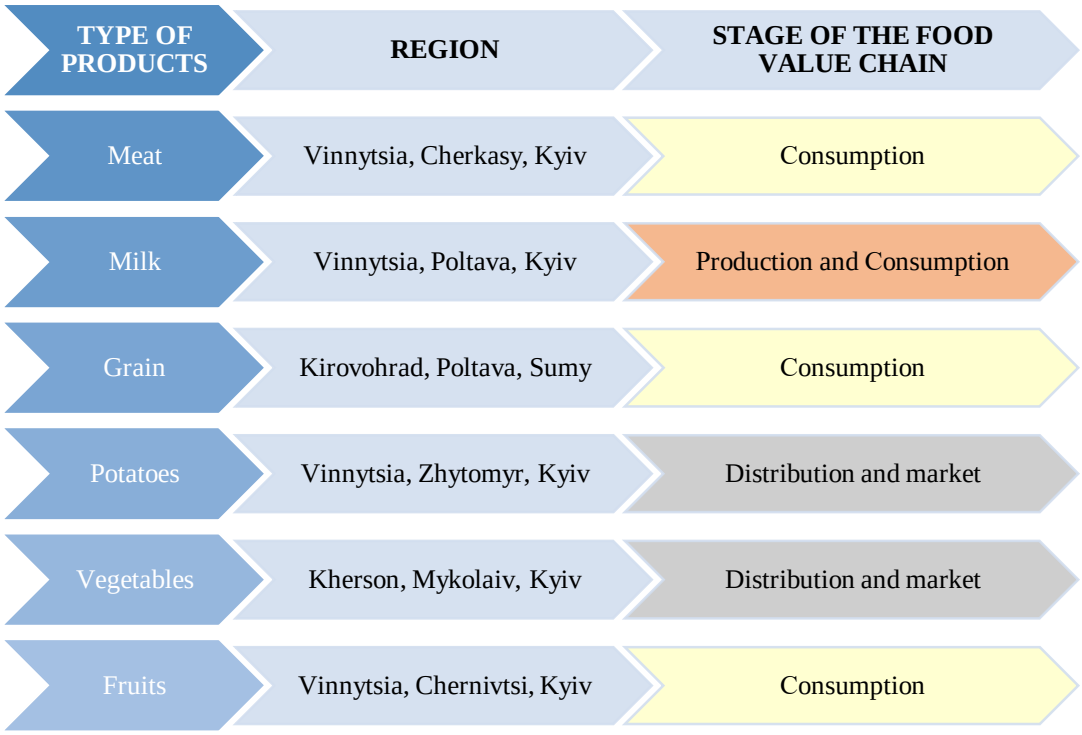

Fig 10. Regions of Ukraine and the stages of the food value chain by individual types of products for which it is necessary to develop measures and policies to reduce food losses and waste. Source: developed by the authors

6. Conclusions

Correlation and regression analysis made it possible to determine the degree of influence of food losses and waste at each of the stages of the food value chain on the total amount of costsfor each of the studied types of products. It was established that the greatest impact on the amount of food losses and waste per person occurs at the stages of production and consumption, except for potatoes and vegetables – the greatest impact on the amount of food losses in these groups is lost at the stage of delivery and sale, at the same time, food losses at the stage of handling and storage have the least effect on the effective indicator – physical restriction of access to food. Consequently, the amounts of food losses and waste differ significantly at each stage of the food value chain and are significantly differentiated depending on the type of productand region.

The sustainability of the system is determined by the possibility of introducing technologies and policies of conducting agrarian business, as well as consumption culture, which bring the system closer to zero food losses and waste. In this regard, appropriate practices for Ukraine are the introduction of technologies for deep processing of products, especially damaged food products, which will contribute to a significant reduction of food losses at the Distribution and market stages. Educational activities and promotion of healthy eating are necessary elements of "smart consumption", which will contribute reduction of food losses and food waste at the Consumption stage. Diversification of technologies has always been one of the most effective tools for reducing risks and preventing losses. This approach is effective at any stage of the food value chain. However, in the conditions of the aggressive and destructive war waged by the Russian Federation on the territory of Ukraine, diversification is one of the main tools for balancing the food system. These results are important for decision-making in the sphere of achieving the objectives of the SDG 2 and planned target indicators in Ukraine.

In the future, it is necessary to develop a general framework of action and policies to reduce food losses and waste to achieve zero hunger.

7. Limitations and further research

This research has limitations that may be associated with the used methods. In this regard, the estimated/assumed waste percentages for each commodity group in each step of the Food Supply Chain (FSC) for Europe are potentially biased. According to the FAO methodology, theregion "Europe" includes 42 countries, including Ukraine, some other countries of the former Soviet Union, and the Russian Federation (Annex 1. Grouping of world regions) (FAO, 2011). It can be expected that some coefficients may be insufficiently relevant and require adjustment given such a wide range of countries for which the same coefficients are proposed.

It is advisable to conduct further research to refine the estimated/assumed waste percentages for each commodity group in each step of the FSC for Ukraine.

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