

# Food Loss and Food Waste Along the Food Supply Chain – An International Perspective

## Straty i marnotrawstwo żywności w łańcuchu dostaw – perspektywa międzynarodowa

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### Abstract

Food loss and waste represents a global problem which is characteristic for all food supply chain sectors and all groups of countries. On average, every year one third of the total amount of food produced is lost or wasted, which indicates an extremely high level of inefficiency in the food supply chain. One of the key characteristics of food loss and waste is a wide range of ecological, economic and social implications, which is why this problem has become the subject of many national and global agendas. Although there is still no unique definition of the term food loss and waste and unique data collection methodology, many authors have researched this topic so far. Therefore, this paper's aim was to research the existing literature on the phenomenon of food loss and waste, as well as to observe trends of the amount of food loss and waste in the world and the EU. The results indicated that the differences between developed and developing countries have changed, and the amount of food waste in both groups of countries at the household level is now quite uniform. At the level of the EU, the household sector is also the largest generator of food waste.

**Key words:** food, supply chain, food loss, food waste

### Streszczenie

Straty i marnotrawstwo żywności stanowią problem globalny, charakterystyczny dla wszystkich sektorów łańcucha dostaw żywności i wszystkich grup krajów. Średnio co roku jedna trzecia całkowitej wyprodukowanej żywności jest tracona lub marnowana, co wskazuje na niezwykle wysoki poziom nieefektywności w łańcuchu dostaw żywności. Jedną z kluczowych cech utraty i marnotrawienia żywności jest szeroki zakres implikacji ekologicznych, ekonomicznych i społecznych, dlatego problem ten stał się przedmiotem wielu agend krajowych i globalnych. Choć nadal nie ma jednoznacznej definicji pojęcia straty i marnotrawstwa żywności oraz unikalnej metodologii gromadzenia danych, wielu autorów zajmowało się już tym tematem. Dlatego też celem niniejszej pracy było zbadanie istniejącej literatury dotyczącej zjawiska strat i marnotrawienia żywności, a także obserwacja trendów wielkości strat i marnotrawienia żywności na świecie i w UE. Wyniki wykazały, że różnice pomiędzy krajami rozwiniętymi i rozwijającymi się uległy zmianie, a ilość marnowanej żywności w obu grupach krajów na poziomie

gospodarstw domowych jest obecnie w miarę jednolita. Na poziomie UE sektor gospodarstw domowych jest także największym generatorem marnowania żywności.

**Słowa kluczowe:** żywność, łańcuch dostaw, straty żywności, marnowanie żywności

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## 1. Introduction

The food supply chain is a complex network of interconnected entities. The most important function of the food supply chain is the production and distribution of health-safe products to end consumers. (Webster, 2001). Complexity of the food supply chain is specific by the perishable nature of the goods that move along the food supply chain, the interaction of many stakeholders and cross-sector influence (Chauhan et al. 2021). Millions of tons of food are produced, processed and transported along the food supply chain to feed the world's population (Ishangulyyev, Kim and Lee 2019).

Globalization and changing consumer preferences are increasing the distance between places of food production and consumption, which affects the length, complexity and the number of participants in the food supply chain (Mokrane et al. 2023). The number of participants in the food supply chain is increasing, and the path that food takes from the place of production to the place of consumption (food miles) is getting longer and requires large amounts of energy, water, land and other resources. Along the way, numerous environmental problems arise, such as adverse effects on biodiversity, climate change and the emission of greenhouse gases, soil and water pollution (Damjanović, Živanović and Vasilkov, 2022). The generation of large amounts of packaging waste and the increasingly significant problem of food loss and waste that are thrown away along the entire supply chain is also very important. If the amount of the produced food is wasted, the total effort and resources used for it are wasted too. There is water and air pollution, soil erosion and consumption of resources to produce food that will ultimately never be consumed (Ghosh et al., 2015; Živković, Petrović and Protić, 2021). This problem is characteristic for all parts of the world and for every segment of the food supply chain, from the agricultural sector, through the food industry, wholesale, retail, and hospitality sector to the consumer. Although waste is generated at all stages, some segments of the food supply chain have received far greater attention due to their greater propensity to generate waste. The problem of food waste and loss is characteristic of all types of food products and all groups of countries, both developed and developing countries. On average at the world level annually are thrown away 30% of the total amount of produced cereals, 40-50% of roots, fruits and vegetables, 20% of oilseeds, 30% of meat, dairy products and fish (Gustavsson, Cederberg and Jonesson 2011; Lipinski et al., 2013).

According to Gustavsson, Cederberg and Jonesson (2011), every year one third of the total amount of food produced is lost or wasted in the world, which would be enough to feed about 2 million inhabitants (Ghosh et al., 2015). Measured in calories along the food supply chain, 24% of production is lost, or thrown away, that is, every fourth calorie. Such data indicate a very high level of inefficiency in the food supply chain with significant economic, environmental and social implications. More precisely, besides exacerbating the problem of hunger and malnutrition the food loss and waste is contributing to environmental pollution through the pressure on the climate, land and water resources. Because of that the problem of food loss and waste is increasingly considered in various national and global strategies and agendas. For example, the fight against food loss and waste represents a segment of the 12th UN Sustainable Development Goal (SDG) which refers to sustainable consumption and production. This goal calls for halving the amount wasted food in the retail sector and by consumers worldwide by 2030 and reducing post-harvest food loss (United Nation, 2023). Considering the food loss and waste social, economic and environmental implications, the achievement of this goal can also indirectly contribute to the achievement of other SDGs such as SDG 2 (Zero hunger), SDG 6 (Clean water and sanitation), SDG 8 (Decent work and economic growth), SDG 11 (Sustainable cities and communities), SDG 13 (Climate action), SDG 15 (Life on land). The European Union is paying more and more attention to the problem of food loss and waste too. Reducing food loss and waste is an integral part of the farm to fork strategy which is central to the European Green Deal (European Commission, 2023a). The Farm to Fork strategy (European Commission, 2023e) aims to ensure the sustainability of food production within all segments of the food supply chain. Because of that, EU member states must implement appropriate measures to reduce the amount of wasted food by 10% in the food industry and by 30% at the level of consumption that is within the retail, catering sector and household level until 2030.

Considering the above, the aim of the paper is to research the existing literature on the concept of food loss and waste in the food supply chain with a special emphasis on the problem of defining the concept, its causes and implications. In addition, the paper's goal involves the analysis of previous research to establish the trend of the amount of food loss and waste in the world and the EU. After the introduction, the first segment of the results considers the problem of defining the concept and the difference in defining the concepts of food loss and food waste. The second part analyzes the places in the supply chain where food loss and waste occur, as well as the most common causes that lead to their occurrence. The next segment analyzes the social, economic and environmental implications of the food loss and waste in the supply chain. The third part includes an analysis of the amount of food loss and waste in the world and the EU, while the last part refers to concluding considerations.

## 2. Methodology

The Scopus database was used for the reference selection procedure, and the following keywords were used during the search: food waste, food loss and food supply chain. Most of the papers included in the analysis refer to the period after 2011, when the FAO organization published the first significant analysis of the problem of food loss and waste, which served as the basis for all subsequent analyzes. Although this problem covers a much wider range of fields due to its numerous implications within the scope of the search, only articles and reviews from the fields of Agricultural and Biological science, Business, Management and Accounting as well as from the fields of Economics, Econometrics and Finance were considered. Also, only works in English were considered. Apart from the Scopus database, the analysis included a certain number of works that were listed in the bibliography of the works taken from the Scopus database.

Different definitions of food loss and waste, the absence of common standards related to the collection of data around the world make it somewhat difficult to understand the causes of their occurrence and to determine the exact proportions of the amount of food waste. In this regard, this paper's objective is based on reviewing existing literature, publications and reports created by leading organizations dealing with food loss and waste.

That is, the assessment of the amount of food loss and waste at the world level along the food supply chain is an integral part of SDG12.3 of the United Nations. According to United Nations (2023), this goal aims to halve the amount of food wasted in retail and by consumers at the global level and to reduce the amount lost after harvest until 2030. To determine the amount of food wasted or lost along the supply chain and to monitor progress in achieving SDG 12.3, organizations FAO and UNEP have developed two indices: Food Loss Index (FLI) and Food Waste Index (FWI). The FLI was developed by the FAO organization and indicates the amount of food that is lost at the initial stages of the food supply chain up to, but not including, the retail sector. The calculation of this index includes food and inedible parts, and it is calculated for 5 different groups of products, while for each group 10 products that are the most significant from the aspect of production value were selected (FAO, 2019). The FWI was created by UNEP with the intention of establishing the amount of food that is wasted at the level of the retail, catering and consumer sectors. When calculating the food waste index, edible and inedible parts of food are also included, but unlike the food loss index, it is not calculated for specific but for all agricultural and food products. However, these two indices must be viewed and analyzed separately. More precisely, given the methodological differences that exist between these two indices, it is not possible to combine them and accurately determine the amount of food waste along the food supply chain (UNEP, 2021).

## 3. Results and discussion

### 3.1. *The problem of defining the concept of food loss and waste*

Food loss and waste is one of the most challenging problems of modern society. To take appropriate measures in the future to prevent and reduce the amount of food waste, it is very important to understand this concept, the difference between the concepts of food loss and waste, to identify the places in the food supply chain where they occur, the implications they have (Santeramo and Lamnaca, 2021), but most of all it is important to have knowledge and awareness of the importance of the environmental problems (Milojević, Savićević, Dimitrijević, 2023). There is no single definition of the concept of food loss and waste in the supply chain, and many different terms and approaches are still used, which makes the process of comparing different estimates of the amount of food waste more difficult (Boiteau and Pingali, 2023; Corrado and Sala, 2018; Xue et al., 2017).

When defining the same term, different authors use different terminology, and in some cases the same term can even have different meanings. Likewise, depending on the place in the food supply chain where it occurs, some authors consider separately the concept of food loss and the concept of food waste (Lipinski et al. 2013). On the other hand, some authors do not distinguish between these two terms and under the concept of food waste they consider everything that is being lost or wasted along the food supply chain, from the agricultural sector to the consumers (Fusions 2014; Bellemare et al. 2017).

Until now, many authors have dealt with the problem of inconsistency and lack of harmonization in defining the concept of food loss and waste in the supply chain, during which different criteria for the classification of definitions were determined. In their work, the authors Chaboud and Daviron (2017), comparing the definitions of the FAO organization and the European Commission, identified 2 elements by which the definitions of FLW are similar (timing and scope), and 4 elements by which the definitions are different (terminology, criteria, perspective and type of FLW that is considered). Considering the similarities, the authors noticed that the largest number of definitions include the phases of the food supply chain after harvest (timing), and that includes products that are mainly intended for human needs (scope). In the case of differences, the authors concluded that most definitions differ in the terminology that is used, the final purpose of the product, whether only edible or inedible parts of the product are considered, as well as whether only the quantity or quality of the food that is thrown away is considered. Like previous authors, Spang et al. (2019) classify the definitions of food loss and waste based on three criteria. More precisely authors classify definitions based on the phase of the supply chain where it occurs, the

purpose and destination of the products, and whether only edible or non-edible parts of the products are included in the analysis. According to the FAO study (2019), the definitions differ according to what is considered under the term food, whether edible or inedible parts of food are analyzed, which segments of the food supply chain are included in the analysis and whether the quantity or quality of wasted food is considered.

This paper discusses the definitions of food loss and waste in the supply chain based on the stage of the food supply chain in which they occur, whether only edible or inedible parts of the product are included in the analysis, and based on whether the analysis considers the quantity or quality of loss and throws. According to the criterion of the stage of the food supply chain in which food waste occurs, the largest number of definitions includes all stages after harvest (Spang et al., 2019). Considering the opinion of most authors, the problem of food loss is related to the initial stages of the food supply chain, that is, to the agricultural sector, storage and food industry (Hoehn et al. 2023, Gustavson et al., 2011; FAO, 2011; UNEP, 2021). On the other hand, the largest number of authors link the problem of food waste to the lower segments of the food supply chain, i.e. from the retail sector to consumers (HLPE 2014; Gustavson et al., 2011; FAO, 2011; UNEP, 2021). However, USDA defines food waste as part of food loss (Buzby, Wells and Hyman 2014), while Fusion (2014) equates these two terms regardless of which segment of the supply chain they originate in. In the case of the criteria of edibility or inedibility of the product, different authors define the concept of food loss and waste differently, depending on whether the definition includes only edible or inedible parts of the products, such as eggshells, fruit and vegetable peels, bones (FAO, 2011; UNEP, 2021; Fusion, 2014). The question of the edibility of certain parts of the product is, among other things, a question of socio-cultural differences, and what is considered edible in certain countries is not edible in other countries (WRAP, 2018). Bearing in mind these terminological differences, comparing food waste estimates in different countries is very difficult, which is why authors Chaboud and Daviron (2017) believe that it would be more appropriate if there were no differences in defining the concept of food loss and waste between edible and inedible parts of the product. According to Razaei and Liu (2017), food loss and waste as a phenomenon imply a reduction in the quantity and quality of food intended for human consumption. The quantitative aspect of food loss and waste refers to the reduced mass and quantity of food intended for human consumption in bulk, while the reduction in quality implies a reduction in attributes, i.e. physical, chemical and organoleptic properties of food (FAO, 2019; FAO, 2014). Qualitative loss is related to quantitative loss when a certain food product has lost its qualitative properties to such an extent that it must be removed (HLPE, 2014). Due to simplicity, a much larger number of authors analyzed the quantitative aspect of food loss and waste than the qualitative aspect (FAO, 2011; FAO, 2019; UNEP, 2021; USDA ERS 2020).

When defining the concept of food loss and waste, it is necessary to distinguish avoidable food waste from unavoidable waste. Depending on whether it is possible to prevent the occurrence of food waste or not, food waste can be classified into three categories: waste whose occurrence can be prevented, waste with a high potential for its occurrence and unavoidable food waste. Avoidable food waste refers to food that has been thrown away but is still edible. It occurs because of preparing large meals, food damage during meal preparation or because of purchasing large quantities of food products. Unavoidable waste mainly means waste that is created during the preparation of meals, and includes inedible parts of food such as eggshells, peels from fruits and vegetables, bones. What is certainly clear is that in the future, attention should be directed towards reducing the amount of waste that can be avoided (Ishangulyyev, Kim and Lee 2019).

### *3.2. Causes of food loss and waste along the food supply chain*

There are many factors that lead to the occurrence of food loss and waste along the food supply chain, and identifying and understanding these factors can lead to a long-term reduction in the amount of food wasted and an increase in the efficiency of the food supply chain (Table 1). Analyzing the factors that cause food loss and waste along the food supply chain has been the subject of research by many authors for a long time.

Razaei and Liu (2017) and Gille (2013) argue that in the agricultural sector, food loss mainly occurs because of bad weather, pests and diseases, mishandling of the food production and delivery process, and untimely harvesting. The problem of food loss can also arise because of a lack of managerial skills in the process of agricultural raw materials production (Lipinski et al., 2013), due to the limitations of agricultural techniques, more precisely because of the application of inadequate methods and equipment during the production and harvesting process (Ghosh et al., 2015; Xue et al. 2017). Likewise, some agricultural products are thrown away after the end of production process because they do not meet the quality standards required by processors (Garrone, Melacini and Perego, 2014; Papargyopoulou et al., 2014). Limitations such as the absence of adequate storage space that has the appropriate amount of light, humidity, temperature and oxygen level (Wunderlich and Martinez, 2018) and inadequate handling of raw materials during transport due to underdeveloped infrastructure. Also, the long distances that the product often travels from the place of production to the place of consumption further aggravates this problem. Santeramo and Lamonaca (2021) claim that food loss can also be caused by price volatility that affects the level of stocks in warehouses. The authors believe that if the prices of a certain agricultural product are below expectations, it is better to store that product and wait for more favorable conditions on the market. However, waiting too long can lead to spoilage of the agricultural product and thus increase the amount of food loss. Food

loss also occurs in the food industry due to damage in products or packaging that very often do not meet quality and safety standards, which is why they are rejected (European Commission, 2023b; HLPE, 2014; Papargyopoulou et al., 2014). Overproduction, especially of products that have a shorter shelf life and require special cooling systems (Kaipia, Dukovska-Popovska and Loikkanen, 2013), as well as frequent changes in production methods within the food industry and contamination of production lines can lead to an increase in the amount of food loss (Beretta et al., 2013).

Table 1. Food loss and waste causes, source: authors work

	Food supply chain sector	The cause of food loss and food waste	References
Food loss	Agricultural sector	Bad weather, pests and diseases; Inadequate handling of the production process; Untimely harvesting; Lack of managerial skills in the production process; Limitations of agricultural techniques; Failure to meet quality standards required by processors.	Razaei and Liu (2017); Gille (2013); Lipinski et al. (2013); Ghosh et al., 2015; Xue et al. (2017), Garrone, Melacini and Perego (2014); Papargyopoulou et al. (2014)
	Warehouses	No storage or inadequate storage conditions; Price volatility.	Wunderlich and Martinez (2018); Santeramo and Lamonicaca (2021)
	Transport	Poor handling of products during transport; Large distances from the place of production to the place of consumption.	Lipinski et al. (2013)
	Food industry	Product damage; Inadequate or damaged packaging; Failure to meet quality and safety standards; Excessive production; Frequent changes in production methods; Contamination of production lines.	European Commission (2023b); HLPE (2014); Papargyopoulou et al. (2014); Kaipia, Dukovska-Popovska and Loikkanen (2013); Beretta et al., (2013)
Food waste	Wholesale and retail	Inadequate packaging and handling of products; Delay in transport; Inadequate storage conditions for easily perishable products; Poor inventory management; Lack of demand for certain products at certain times of the year.	Lipinski et al. (2013); European Commission (2023b)
	Hospitality sector	Inadequate portion sizes; Consumer preferences; The problem of predicting the number of customers.	European Commission, (2023b)
	Households	Value of average household income; Number of household members; Consumer behavior; Purchase patterns; Insufficient planning of purchases and meals; Impulsive purchases; Misunderstanding of the dates displayed on products by consumers.	Ghosh et al. (2015); Lipinski et al. (2013); European Commission, (2023b)

According to Lipinski et al. (2013) food waste is the result of a conscious decision to throw away food. The most significant factors that lead to the creation of waste within the wholesale and retail sector include inadequate packaging and handling of products, delays in transport, inadequate storage conditions for perishable products (Lipinski et al., 2013), poor inventory management, as well as lack of demand for certain products in a certain period of the year (European Commission, 2023b). In the case of the hospitality sector, food waste can be separated into two groups, kitchen waste and plate waste. Kitchen waste most often includes inedible parts of food such as peels from fruits and vegetables, eggshells, and bones created during meal preparation. Waste on the plate in the hospitality sector is mostly a result of inadequate portion size or consumer preferences and habits. Food waste in the hospitality sector can also occur due to difficulties in predicting the number of customers (European Commission, 2023b). At the household level, food waste mainly occurs as a result of average household income, number of household members, consumer behavior and purchasing patterns, (Ghosh et al., 2015, Lipinski et al., 2013), misunderstanding of the dates displayed on labels by consumers (due date, best before, use by date, sell date etc.), insufficient planning of purchases and meals as well as impulsive purchases (European Commission, 2023b). In addition to the previously mentioned, there is also a category of systemic factors that most often relate to an inadequate political, institutional and regulatory framework, which in certain cases additionally contribute to the generation of large amounts of food loss and waste along the supply chain. These factors include inadequate policies that create unstable prices that cause producers to choose to leave their produce unharvested in the fields. Likewise, too strict regulations on food quality represent an obstacle for producers and processors, and inadequate fiscal policy by excessively reducing the prices of agricultural products leads consumers to increase demand, because of which most of the products end up in landfills (HLPE, 2014). Crisis situations such as wars, pandemics

and natural disasters significantly worsen the efficiency of local, regional and global food supply chains, thus contributing to deepening the problem of food loss and waste (FAO, 2022).

Regardless of the place and cause of food loss and waste, it should be borne in mind that this phenomenon has several harmful implications that can be classified into three groups: social, economic and ecological implications which are considered in the next section.

### *3.3. Food loss and waste implications*

In the past few decades, food production has increased significantly to meet the nutritional needs of a growing population. However, parallel to the growth of the amount of food produced, the amount of food waste along the supply chain has also increased with significant social, ecological and economic implications (Mokrane et al. 2023).

Hunger as a phenomenon has not yet been eradicated, and while about a third of all food produced is thrown away annually (Gustavson et al., 2013), 828 million people around the world are hungry and malnourished (FAO, IFAD, UNICEF, WFP, WHO, 2022). Abbade (2020) estimates that the total amount of food lost and waste along the food supply chain could contribute to feeding 939 million adults with a daily intake of 2,000 calories per person. In the European Union, about 59 million tons of food are thrown away annually, while there are about 32.6 million inhabitants unable to afford a quality meal (Eurostat, 2023). The social implications of food loss and waste significantly affect the problem of food security by reducing local and global food availability (HLPE, 2014), which further worsens the problem of hunger in the world. Reduced availability of food leads to rising prices and less opportunities for low-income categories of the population to buy food. The world's population is still increasing, and to meet the nutritional needs of the growing population in the coming period, food production should increase significantly, which could additionally lead to the worsening of the problem of food loss and waste. The social benefits of reducing food waste include redistributing surplus food to those who really need it. The redistribution of surplus food that would otherwise be thrown away also has a strong ethical dimension and is simultaneously linked to the problem of food safety, waste management and the use of energy from renewable sources (Darnjanović, Živanović and Vasilkov, 2022).

Economically, food loss and waste represent wasted investments, and the annual market value of food lost and waste along the food supply chain is estimated at \$1 trillion per year (Spang et al. 2019). Food loss and waste reduce the economic well-being of all participants in the food supply chain, i.e. they directly affect the reduction of farmers' income and the growth of consumer spending. The economic consequences imply the wasted use of financial, natural and agrarian resources to produce food that ends up in the landfill (NALED, 2022). The level of economic implications, i.e. costs, differs for different groups of countries and for different stages of the food supply chain. That is, according to Mokrane et al. (2023) high-income countries have higher costs from food waste in the lower segments of the food supply chain, while low-income countries experience greater losses in the initial stages of the food supply chain.

The life cycle of food begins on farms and continues through transportation, storage, processing, distribution and consumption. Along the way, significant amounts of greenhouse gases are emitted, and large amounts of water and soil resources are consumed. The generation of large amounts of food waste that ends up in landfills further exacerbates the previously mentioned environmental problems. Lipinski et al. (2013) believe that ecological implications contribute to environmental pollution to the greatest extent through global warming and climate change impacts and lead to the wastage of scarce resources. Throwing large quantities of food into landfills releases enormous amounts of greenhouse gases such as carbon dioxide, methane and nitrous oxide. According to FAO (2015) food loss and waste are responsible for an estimated 8% of annual greenhouse gas emissions. In addition, food loss and waste are associated with the annual consumption of approximately 173 billion cubic meters of water, which is 24% of the water used for agricultural production. Likewise, about 198 million hectares of arable land are used annually to produce food that will eventually be thrown away, thus contributing to the degradation of natural ecosystems and the loss of biodiversity (Lipinski et al., 2013; FAO, 2022). It is very important to note that the environmental implications of food loss and waste vary from country to country and at the same time depend on the stage of the food supply chain as well as the type of product produced (Mokrane et al., 2023). Therefore, reducing the amount of food that is lost or wasted along the food supply chain can be one of the main ways to achieve sustainable food production in the future (Lipinski et al., 2013), and more educational actions should be introduced to avoid and minimize food loss and food waste (Kostecka, Garczyńska, Pączka, 2018).

### *3.4. Food loss and waste at the world*

Food loss and waste is a worldwide problem that is considered one of the major obstacles to achieving sustainable development. Until now, many authors have analyzed this problem on a global level, and one of the first studies is the study by the authors Gustavsson, Cederberg and Sonesson (2011), who in their work analyze the total amount of wasted food considering 7 regions for the year 2007. The authors concluded that about one third of the world's total food produced is thrown away annually, about 1.3 billion tons of food per year. They also concluded that food is wasted along the entire food supply chain from the agricultural sector to final consumption, both in high,

middle and low-income countries. Analyzing the amount of food thrown away in the world and the resources used to produce it, Kummu et al. (2012) concluded that approximately a quarter of the total food produced is wasted along the food supply chain (614 calories per capita per day), and that about 24% of the total amount of water, 23% of the total area and 23% of the total amount of fertilizers that are normally used for agricultural production. In their work, Porter et al. (2016) analyze the amount of food waste along the food supply chain in the world for the period 1961-2011 and its impact on the environment. Using FAOSTAT data on the food balance, the authors concluded that in the analyzed period the amount of wasted food in mass increased by 3 times, which also induced an increase in the average emission of gases with the greenhouse effect of 44%.

Based on the FAO FLI, it is estimated that globally around 14% of food is lost in the post-harvest to retail sectors. Considering the different group of products, in the initial stages of the food supply chain tubers and oil crops (25.3%), fruits and vegetables (21.6%), meat and meat products (11.9%), cereals and legumes (8.6%) and other products (10.1%) are mostly lost products (Figure 1). Such a high percentage of loss is expected for fruits and vegetables given the perishable nature of these products (FAO, 2019). On Graph 1, it is evident that in 2016, at the regional level, the largest amounts of food were lost in Central and South Asia (20.7%), while the smallest percentage was lost in Australia and New Zealand (5.8%). However, according to the data of the food loss index for 2021 (FAOSTAT, 2023), the situation in the world has changed significantly. More precisely, in 2021, the largest amounts of food losses were generated in the region of sub-Saharan Africa (19.95%), and the least in North America and Europe (9.19%). In addition, considering the regions of the world individually, the percentage of food loss in 2021 increased compared to 2016 in all regions, except in the Central and South Asian region, as well as in the North American and European regions, where there was a decrease.

Regarding food waste, according to the UNEP (2021) report, in 2019, around 931 million tons of food was wasted in the world, which is 121 kg per inhabitant. Of the total amount of wasted food, 61% originates from households (569 million tons), 26% in the catering sector (244 million tons), while 13% was thrown at the level of the retail sector (118 million tons). These data indicate that 17% of the total amount of food produced was wasted.

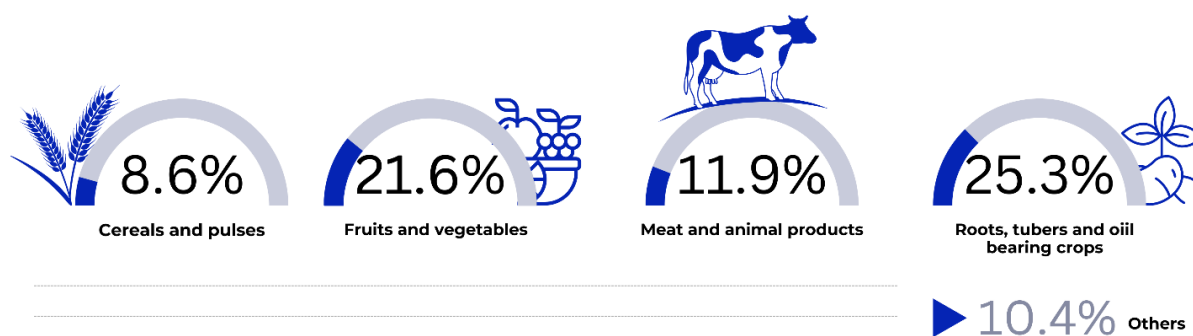
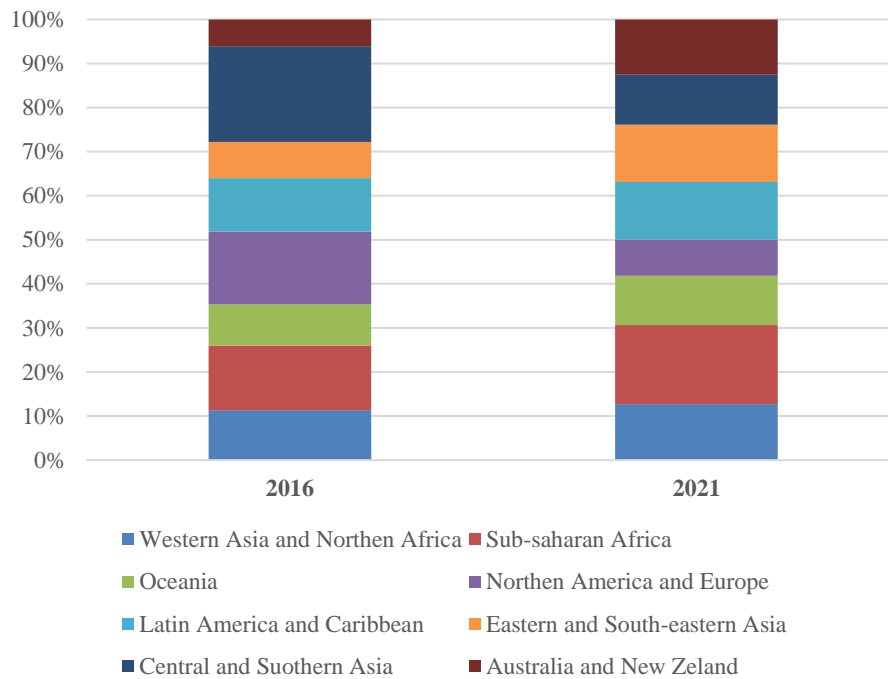


Figure 1. Food loss by commodities group, source: authors work based on data of FAO, 2019

Previous research has shown that in different groups of countries there are significant differences in the places in the food supply chain where most food loss and waste are generated. According to earlier research (Panait et al., 2020; Gosh et al., 2015; Lipnski et al., 2013; Gustavsson, Cederberg and Sonesson, 2011), more than half of food waste in developed countries was generated in the lower segments of the food supply chain, that is in the retail sector, the hospitality sector and at the household level, while for developing countries the situation was completely opposite. More specifically, previous research indicated that food loss occurring at the initial stages of the food supply chain was a major feature of developing countries. However, the latest UNEP study (2021) showed that the situation has changed significantly and that the amount of food wasted in the lower stages of the food supply chain, especially at the household level, is quite uniform in both groups of countries. The tendency to equalize the amount of food thrown away at the household level is to the greatest extent caused by the growth of the economic standard in developing countries in the past period. The growth of living standards in developing countries has led to the improvement of infrastructure and production conditions, and thus to a change in the place in the food supply chain where food loss and waste occurs in those countries. Also, economic growth had a significant impact on the increase in the standard of living of consumers, and the growth of consumer income led to a change in the structure of consumption in the direction of increased demand for perishable categories of products such as fresh, fruit, vegetables and meat (Nicastro and Carillo, 2021).

### 3.5. Food loss and waste at the European Union

EU members are also committed to fulfilling SDG 12.3 of the United Nations, and reducing food loss and waste is an integral part of the strategy Farm to Fork which is focused on creating a fair, healthier and ecological food system (European Commission, 2023e). To speed up the achievement of this goal, the European Commission has proposed that by 2030, member states reduce food waste in the food industry by 10% and 30% in the retail sector, the hospitality sector and in households (European Commission, 2023c).



Graph 1. Food loss by world regions, source: authors work based on data of FAO, 2019 and FAOSTAT, 2023

A certain number of authors dealt with the analysis of the problem of food loss and waste in the European Union, and one of the first works is the work of Monier et al. (2010). In the paper, the authors, looking at the entire food supply chain in the EU-27 for 2006, except for the agricultural sector, estimated the annual production of food waste at 89 Mt, which is 179 kg per capita. Likewise, the results of the FUSION study (2016) indicate that in 2012, 88 million tons of food waste was generated along the food supply chain at the EU-28 level, which is 173 kg per inhabitant. The authors also concluded that, with a 72% share in total waste, households and the processing sector are the sectors which contribute to this problem in the EU the most. The rest is made up of the hospitality sector, which generates 11 million tons of waste (12% of total waste), followed by the agricultural sector, retail and wholesale.

According to Eurostat data (2023), almost 59 million tons of food waste (131 kg/inhabitant) was generated in the EU in 2020 with a market value estimated at 132 billion euros. Considering the structure of waste generated in the EU supply chain, households produced the largest part of waste, which is 53% of food waste, which is 70 kg per inhabitant. The remaining 47% was generated upstream in the food supply chain. Household food waste is almost double that of food waste generated from the primary production and food and beverage production sectors (14 kg and 26 kg per capita; 11% and 20%, respectively), sectors in which there are strategies to reduce food waste. In restaurants and food services, 12 kg of food waste per person (9%), while retail and other food distribution is the sector with the smallest amount of waste (9 kg; 7%) (Figure 2).

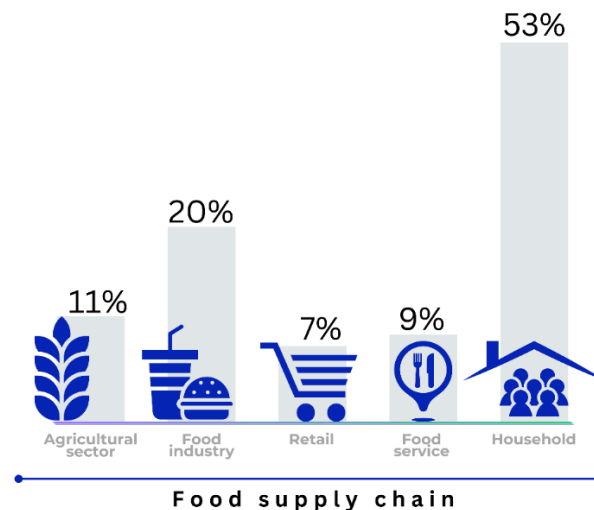
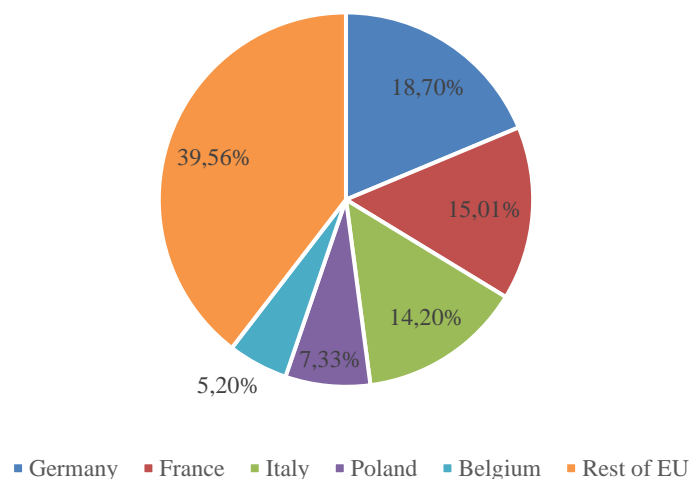


Figure 2. Food waste along the EU food supply chain, source: authors work based on data of Eurostat (2023)





Graph 2. Food waste in the EU member states, source: authors work based on data of Eurostat (2023)

Individually in the EU in 2020, food waste was mostly generated by the following member states: Germany (18.7%), followed by France (15.01%), Italy (14.2%), Poland (7.33%) and Belgium (5.2%) (Graph 2). Together, these members generated 60.4% of the total food waste in the EU.

#### 4. Conclusion

Food loss and waste are a global phenomenon characteristic for all groups of countries, all food products and all sectors of the food supply chain. This phenomenon is caused by numerous factors that differ depending on the sector of the food supply chain in which they occur. One of the key characteristics of this phenomenon is the wide range of implications that are classified into three groups: social, economic and environmental, which is why this phenomenon is increasingly considered in various national and global strategies and agendas. Considering the wide range of implications, the fight against food waste should involve the cooperation of all key actors from the public and private sectors to better identify, measure, understand and find solutions to deal with this problem. Likewise, due to the perishable nature of produce and the complexity of the food supply chain, there is no single cause with a single solution, and all participants in the chain need to work together to find solutions, from agricultural producers, processors, and retailers to consumers themselves.

Despite the inconsistency of the definition between different authors the literature search indicated the inefficiency of the food supply chain in all regions of the world which affects the generation of large amounts of food waste. Although earlier research has shown that there are significant differences between developed and developing countries at the global level based on the places in the food supply chain where the most waste is generated, the latest research indicates that due to the rise in living standards, the amount of food waste at the household level in both groups countries have become quite uniform. The analysis of the food loss index showed that in 2021, the amount of food loss increased compared to 2016 in almost all regions of the world, except in the Central and South Asian region, and in the North American and European regions, where there was a decrease. Also, at the level of the European Union, a tendency to decrease the total amount of food waste along the food supply chain has been observed. Also, in the EU the household sector represents the largest generator of food waste, as is the case at the global level.

Bearing in mind the heterogeneity of the definitions of the concepts of food loss and waste, the diversity of methodologies for collecting and processing data, as well as the wide range of implications of this phenomenon, for the purposes of future research it is of great importance to find a single definition and establish a homogeneous, interdisciplinary methodology that will enable the determination of accurate data on the amount of food wasted as well as a better understanding of the seriousness and breadth of the issues.

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