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FOOD WASTE IN EU COUNTRIES

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Abstract: *The biggest challenges of our time include meeting the demand growth resulting from the explosion in population growth and achieving sustainable management. In terms of food, the most significant problem is, on the one hand, that a large part of the population is hungry and, on the other hand, excessive food waste, which results not only in wasted food but also in wasted resources used for its production, transport, packaging and storage. Do to this the unconsumed food has a profoundly negative impact on the environment and the economy. There is a pressing need to prevent and reduce food waste to transition to a resource-efficient Europe. In this study, we would like to show how food waste changes in different countries, focusing on Europe. Our results show a significant discrepancy between Member States' data and where waste is generated. We find no significant correlation between GDP per capita and total food waste, but we find a moderately strong correlation between GDP per capita and restaurant waste at the point of generation.*

INTRODUCTION

Food wastage is essential to global food security and good environmental governance, which are closely related to environmental (e.g. energy, climate change, water, availability of resources), economic (e.g. resource efficiency, price volatility, increasing costs, consumption, waste management, commodity markets) and social (e.g. health, equality) impacts (Stenmarck et al., 2016). Of these factors, the efficiency of economic factors is perhaps the easiest to measure, as there are different levels of indicators available (Nábrádi et al., 2008, Kovács-Szűcs 2020). Efficiency measurement has been used in many sectors to assess performance and the impact of government decisions (Kovács, 2014).

Different studies show that between 1/3 and 1/2 of the world's food production is not consumed (Gustavsson et al., 2011; Bio Intelligence study, 2010), leading to negative impacts throughout the food supply chain, including households. Consumer awareness is also a significant factor in relation to food waste, Bauerné et al. showed in their study that conscious food consumer behavior is present to varying degrees among young people and environmental awareness comes to the fore among conscious food consumers, and in many cases they avoid food waste, as compared to those who do not consider themselves to be health- and environment-conscious (Bauerné Gáthy et al., 2022).

There are several definitions of food waste. The definition of FUSIONS is in line with the official definition adopted by the European Commission (EU, 2018), except that the latter does not include crops ploughed back into the soil or not harvested.

Food loss is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retailers, food service providers and consumers (FAO, 2021). Food waste refers to all discarded, burned or otherwise disposed of along the food supply chain from harvesting/cutting/catching to the retail level, but is not consumed or used for any other production purpose, such as animal feed or seed (FAO, 2022).

The forms of food waste:
- Fresh food that is not considered optimal (e.g. size, shape or colour) and is discarded during sorting;
- Food that is discarded by retailers or consumers when the expiry date is near or past;
- Discarded, unused or leftover food from households or restaurants (FAO, 2022).

Bibliometric studies provide an intriguing overview of a country's scientific activity and its position in the international aspect, providing essential information to aid those in charge of scientific policy in taking the most appropriate actions (Ser-

toli et al., 2022). A bibliometric analysis was conducted using VOSviewer software on the Web of Science database to map the academic literature on food waste. Thus, we identified essential links by analysing 421 publications' titles, abstracts, and keywords. Only keywords that reached a minimum of 3 occurrences were analysed. Thirty-nine keywords achieved this, which were classified into 5 clusters (Figure 1.). This number has been significantly reduced to explore the most im-

portant links between the literature, and a narrowing has been carried out by searching keywords of food waste in the EU.

In Figure 1. we can see the essential links to food waste. On the one hand, connections can be demonstrated with industry, food safety, mitigation, recycling, attitudes, sustainability, etc. Another side is emission, energy, circulation economy, reduces. This study focuses on the connection between food waste reduction, supply chain, and European Union topics.

Figure 1: Food waste in VOSviewer

Source: VOSviewer software on the Web of Science database, 2022

Latest estimates suggest that approximately 931 million tonnes of food waste were generated in 2019 in the world, of which 61% came from households, 26% from food service, and 13% from retail (UNEP, 2021). Around 88 million tonnes of food waste are generated annually in the EU (Denmark et al. (2016). Our research shows that food waste in the EU is primarily generated at the processing stage rather than by households.

Food waste levels are similar in Europe's high, upper-middle and lower-middle-income countries (UNEP, 2021). In complement to the Food Loss Index, developed by the Food and Agriculture Organization of the United Nations (FAO), the Food Waste Index covers the later stages of food's journey – food waste – occurring at household, food service and retail levels.

Figure 2. summarises specific examples of different types of food waste, grouped by food supply chain stages and major food groups. Figure 2. clearly shows at which stage of the food chain food losses of plant and animal origin occur. In primary production, crop losses are mainly due to unharvested crops, crops left in the field, unsold crops, and rotten or damaged vegetables and fruit. In the case of products of animal origin, this mainly includes food that has not been correctly stored and discarded fish. The second stage is the processing in the food supply chain generated during processing, and it includes animal and vegetable parts which are unfit for human consumption (skin, bones, etc.) and products damaged

during packaging. The third stage is distribution, where the main problems are unsold or expired products and damaged/rejected foods during storage and quality control. The last but not least stage is consumption, where the loss is due to improper storage and non-consumption of food.

Figure 2: Potential food waste by stage in the food supply chain

Stage in food supply chain	Crops	Animals and animal products
Primary production	Edible products not harvested Edible products left in the field Edible products harvested but not sold Rotten fruit or vegetables Products damaged by machines Spillage of products Produce damaged due to mishandling Products stored in poor conditions	Dropped/discarded fish Food lost due to poor storage
Processing	Processing problems (e.g. inefficiency, contamination, etc.) Inedible food waste (e.g. skin, seeds, bones, fruit stones, etc.) Food damaged due to improper packaging	
Distributing	Food damaged due to lack of cooling/storage facilities Expired food Unsold food Food rejected after quality controls	
Consumption	Food damaged due to lack of cooling/storage facilities Food not consumed e.g. due to surplus, expired, inadequate packaging, low consumer appeal and plate waste (i.e. food served but not eaten). Inedible food waste (fruit pulp, bones, etc.)	

Source: adapted from Corrado et al., 2017

As Figure 3. shows, the food waste is divided into edible food products and inedible parts. These constitute the total food waste in the relevant part of the food supply chain.

The FUSIONS framework defines food waste as "any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea" (FUSIONS, 2014).

The inedible parts of food are those parts that are not intended for human consumption, such as bones, crust and pits/ stones. There is no universally accepted definition of the inedible fraction of food waste, which is influenced by several variables, including cultural habits (e.g. pigs' ears or chicken feet are consumed preferentially in some countries), socio-economic factors, food availability and prices, technological development, international trade and geography (EC, 2020).

Therefore, food waste includes parts of food intended for consumption and parts, not for consumption (EC, 2019). However, food waste does not include the following:

- Pre-harvest losses, i.e. losses that occur before the raw material is ready for harvesting or slaughtering, such as weather-related crop damage, which is thus recorded as agricultural waste;
- by-products, i.e. edible or non-edible materials from food production and processing, such as shells, bones and scrapings, which are then used for other purposes (e.g. cosmetics, glues, animal feed);
- food packaging such as cans, protective packaging or plastic containers (although edible packaging is considered food because it is intended for human consumption) (EC, 2020).

Figure 3: Defining the Food supply chain and Food waste
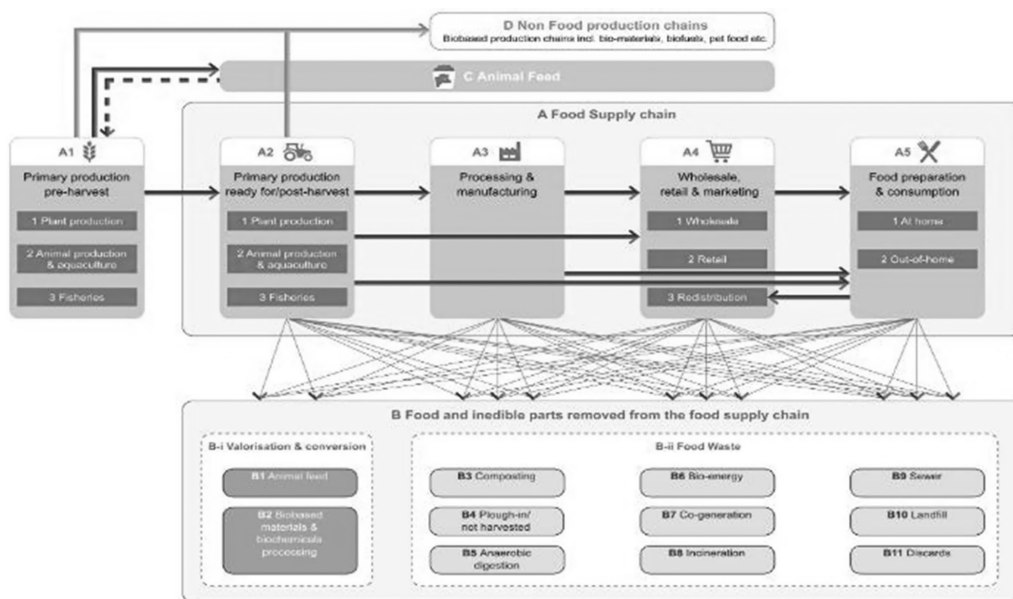
Source: Stenmarck et al., 2016

MATERIALS AND METHODS

This study analysed food waste generated in EU member countries based on the EU's Food Waste Index Report published in 2021.

Two hypotheses were formulated:

H1: The old EU-15 Member States have a higher environmental awareness than the 2004 enlargement countries, suggesting that food waste per capita is lower in the EU-15 than in the 2004 and subsequent accession countries.

H2: In some Member States, food waste generation is mainly due to food wastage at home.

In the analysis, the authors used multivariate statistical analysis methods. Pearson correlation coefficients describe the relationship between the variables and evaluate the development of the relationships between the individual indicators. Relationships and order were analysed using hierarchical clustering based on ward linkage and Euclidian distance. Data analysis was processed using SPSS 25. Where statistical significance is evaluated using p-value without further explanation, we assume a significance level at $\alpha = 0.05$.

RESULTS AND DISCUSSION

There are significant differences in the amount of food waste across the EU, as Figure 4. shows. The most wasteful country is Cyprus, where the amount of waste generated is three times the EU average and almost double that of Denmark, the second-worst performer. Based on the data, a cluster analysis was performed, and the Member States were classified into 3 clusters. Cyprus was placed in the first cluster, as it is the only Member State with an outlier of nearly 400 kg/

year. The second cluster includes 14 countries with food losses exceeding 90 kg/person/year (Denmark, Greece. Portugal, Netherlands, Ireland, Luxembourg, Italy, Norway[1], Lithuania, Austria, France, Germany, Romania, and Estonia). The third cluster is made up of 12 countries where the value is below 90 kg/capita/year (Finland, Poland, Latvia, Hungary, Czech Republic, Spain, Sweden, Belgium, Bulgaria, Slovakia, Croatia, and Slovenia).

Figure 4: Amount of food waste in EU member states, 2020
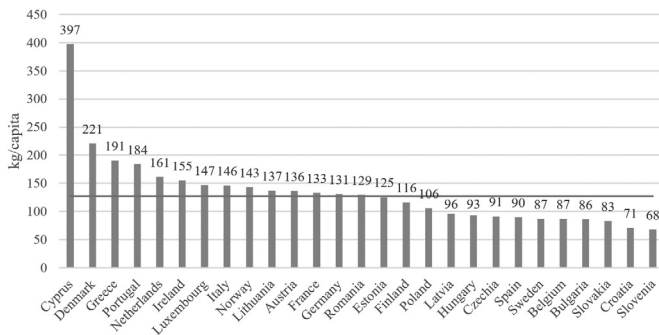
Source: own editing based on EUROSTAT, 2022 data

As Figure 4. and the cluster analysis shows, the old EU Member States are in cluster 2, and the majority of them produce food waste above the EU average, so our first hypothesis (H1) is that the old Member States have higher environmental awareness and therefore lower specific amounts of food waste than the countries that joined in 2004 and afterwards are rejected.

We then looked at the proportions of food waste by place of origin in the Member States. The results are shown in Figure 5. The food waste shows significant differences between countries - in Denmark and Finland 60% of food waste is generated in households, while in Lithuania, the figure is less than 20%. If we express food waste in all countries as 100%, we can see the distribution between places.

Given the outlier value of Cyprus, we assumed that the outlier was since Cyprus is one of the most popular holiday destinations in the EU, with five tourists per inhabitant per year, and therefore the vast majority of food waste generated comes from restaurants and catering waste. However, our proposal had to be rejected for two reasons. Firstly, the database is from 2020, the first year of COVID, when tourism in Cyprus dropped by almost 90%, so many catering outlets were closed or operating at a lower capacity. On the other hand, the compositional data show that this phase generates proportionally the least waste, only 8%. In contrast, half of it is generated during processing.

The results support our second hypothesis that the proportion of the waste generated in each Member State is similar.

Figure 5. shows significant differences between countries in where and how much food waste is generated. If we take the food waste generated in a country as 100%, we can see the proportion of the waste generated in each sector. In primary production, Slovakia has the highest share of total food waste, and

Lithuania and Austria have significant shares too. Denmark has the highest share during manufacturing, followed by Sweden and Slovakia. In the retail and distribution stage, Denmark, Finland, Netherlands, Bulgaria and Romania have the most significant shares. The most striking is that almost all countries' most incredible food waste occurs at the consumption stage.

Figure 5: Proportions of food waste by place of origin in the EU countries
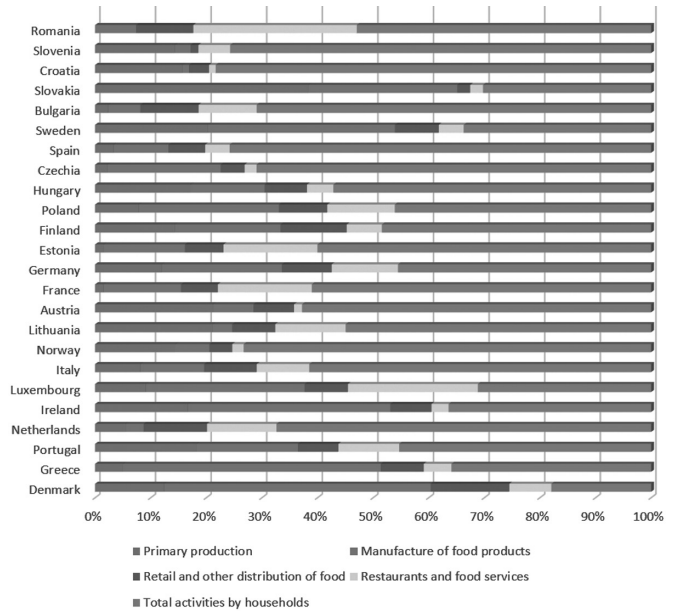
Source: own editing based on EUROSTAT, 2022 data

Our results coincide with the United Nations Environment Programme (UNEP) 2021 report, which also identified the household sector as the primary source of food waste.

In Table 1. we calculated the food waste of the retail, food service and household sectors based on UNEP 2021 data. The UNEP 2021 data differ from EUROSTAT's data, which results from different data, calculations and estimates. We added up the amount of waste generated in each sector, so the Total column in Table 1. gives the amount of food waste people can influence through conscious habits.

Table 1 shows that the average total food waste is 113 kg/capita per year. The highest value is found in Greece (175 kg/capita/year) and Malta (167 kg/capita/year), where household waste is the most significant.

Table 1: The retail, food service and household food waste amount in the European countries (kg/capita/year)

Country	Retail estimate	Foodservice estimate	Household estimate	Total
Albania	16	28	83	126
Andorra	13	26	84	123
Austria	9	28	39	76
Belgium	10	20	50	79
Bosnia and Herzegovina	16	28	83	126

Bulgaria	16	28	68	112
Croatia	13	26	84	123
Czechia	13	26	70	108
Denmark	30	21	81	132
Estonia	5	17	78	99
Finland	13	23	65	102
France	26	24	85	135
Germany	6	21	75	102
Gibraltar	13	26	84	123
Greece	7	26	142	175
Hungary	13	26	94	132
Iceland	13	26	76	115
Ireland	13	56	55	124
Italy	4	26	67	96
Latvia	13	26	76	115
Liechten-stein	13	26	72	110
Lithuania	13	26	76	115
Luxembourg	7	21	89	117
Malta	13	26	129	167
Monaco	13	26	72	110
Montenegro	16	28	83	126
Netherlands	11	26	50	87
North Mac-edonia	16	28	83	126
Norway	14	5	79	98
Poland	13	26	56	94
Portugal	13	26	84	123
Moldova	16	28	76	119
Romania	13	26	70	108
Russia	14	28	33	75
Serbia	16	6	83	104
Slovakia	13	26	70	108
Slovenia	7	20	34	61
Spain	13	26	77	116
Sweden	10	21	81	112
Switzerland	13	40	72	124
Ukraine	16	28	76	119
United Kingdom	4	17	77	98

Source: own calculation, based on UNEP, 2021 data

They are followed by France, Denmark and Hungary, where the high value is also due to high household waste generation. The data of Albania, Bosnia and Herzegovina, Montenegro and North Macedonia are the same (126 kg/capita/year), probably due to similar calculations and estimation methods. In addition to the countries mentioned above, the following countries are above average Iceland, Latvia, Lithuania, Spain, Luxembourg, the Republic of Moldova, Ukraine, Andorra, Croatia, Gibraltar, Portugal, Ireland, and Switzerland. Bulgaria and Sweden's food waste levels are very close

to the average (112 kg/capita/year). The following countries food waste levels have below the average, in descending order: Monaco, Liechtenstein, Slovakia, Romania, Czechia, Serbia, Germany, Finland, Estonia, United Kingdom, Norway, Italy, Poland, Netherlands, Belgium, Austria, Russian Federation, and Slovenia. For each country, it can be established that the most considerable amount of food waste is found in the household sector.

One of the most important indices of the population's food consumption is the quantities of the consumed foods expressed in a natural measure (Balogh, 2008). It would be worth comparing how many percent of the total amount of food consumed is wasted. This fact (the household sector wastes the most food) can be considered favourable from that point of view because the consumption stage is perhaps the easiest way to reduce food waste. With the proper attention and campaigns, consumers could be supported to reduce the amount of food waste in their households.

Table 2: Correlation between each waste generation site and the country's GDP per capita

Correlations			
		GDP/capita	Restaurants and food services
GDP/capita	Pearson Correlation	1	,431*
	Sig. (2-tailed)		,036
	N	27	24
Restaurants and food services	Pearson Correlation	,431*	1
	Sig. (2-tailed)	,036	
	N	24	24
*. Correlation is significant at the 0.05 level (2-tailed).			

Source: own calculation and editing based on EUROSTAT, 2022 data

Finally, a correlation was calculated between each waste generation site and the country's GDP per capita. Our analyses found a moderately strong positive correlation between GDP per capita and the amount of food waste in restaurants (Table 2.). The correlation may be because, in countries with higher economic performance, the population can choose to eat out more often, or restaurant services have taken over the role of home cooking.

By UNEP, 2021 levels of household food waste (the total of edible and inedible parts) are similar for high-income, upper-middle-income and lower-middle-income countries.

For many people on the planet, food is a given, the European consumers benefit from the widest possible choice of quality food products (Bartha et al., 2009). However, for the staggering more than 820 million people who are hungry, food is not a guarantee. Not all countries have sufficient quantities and quality of food, while in other parts of the world obesity is causing socio-economic problems (Vida, 2013). Reducing food loss and waste is critical to creating a Zero Hunger world and reaching the world's Sustainable Development Goals

(SDGs), especially SDG 2 (End Hunger) and SDG 12 (Ensure sustainable consumption and production patterns) (FAO, 2021). So this is the reason why so important to take attention about food waste for each country.

EU's Farm to Fork Strategy has set the reduction of food loss and waste as an important part of the strategy and proposes to set legally binding targets to reduce food waste across the EU by 2023 (EC, 2022).

We, as consumers, can have a direct impact on the food waste problem by paying attention to our own behaviour (Karnai et al., 2021). Make proposals for reduction for each stage/ participant in the food chain, for example a free information booklet to provide recycling opportunities for each product (composting, recipe, school programmes, competitions, camps, other alternative options: community composting, etc.). There is a need for a long-term marketing strategy, an effective information campaign, a well-articulated advertising message, and a way of making consumers aware of this, so that advertising can also have an educational function (Balogh, 2010). Education is important, because in most cases people do not eat and use certain foods, because they do not know how to prepare them properly (Szűcs et al., 2008),which means that food by-products are not used properly, leading to more waste. Less food loss and waste would lead to more efficient land use and better water resource management, positively impacting climate change and livelihoods (FAO, 2021).

Shortening the supply chain would be a key objective for producers, as the shorter the product's journey to the consumer, the less waste is generated. The later food is wasted in the supply chain, the more significant the environmental impact (CO_2 emissions, ecological footprint). Each food has a different impact on the environment. The further along the supply chain the food loss occurs, the more carbon-intensive the loss and waste (FAO, 2011). Improving the figures and implementing targeted programmes can only be achieved through continuous data monitoring.

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