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Household food waste in five territories in Europe and Northern Africa: Evaluation of differences and similarities as implication for actions.

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ABSTRACT

Reduction of food waste is an important element of the sustainable transformation of food systems. This study focused on food waste quantification, its causes, and perception in 5 territories: North Hessia (Germany), Cilento Bio-District (Italy), Kenitra (Morocco), Warsaw (Poland), Copenhagen (Denmark) with the main objective of assessing whether different cultures affected the levels and the profiles of household food waste. A validated questionnaire was used to assess the quantities and typologies of food waste (completely unused, partially used, meal leftovers, leftovers after storing). In addition, the reasons for food waste and how food waste was perceived were investigated. In a sample of 2154 respondents, the level of still edible food that was wasted amounted to 399 g per family per week, equivalent to 153 g per capita. Kenitra showed the highest amount of FW per household (539 g), but the lowest amount of food waste per capita (125 g). Citizens of rural communities, e.g., Cilento Bio-District (136 g), North Hessia Federal State (132 g), and Kenitra (125 g), had more effective food waste prevention practices than citizens of urban areas, e.g., Copenhagen (201 g) and Warsaw (179 g). Family size was identified as a significant factor in FW generation, with households having 5 or more members showing lower FW per capita (85 g) than single-member families (309 g). The study underscores the need for tailored strategies to reduce FW considering the above-reported territorial differences.

1. Introduction

The agri-food system has both economic and environmental impacts, consuming resources such as water, soil, and fuels (Mekonnen and Hoekstra, 2011); each stage of the supply chain determines a loss of resources (De Corato, 2020). The environmental impact of food production is exacerbated by food loss and waste (FLW), which causes more energy to be consumed for disposal and increased production demand (Kummu et al., 2012; Scherhaufer et al., 2018). For these reasons, one of the steps to mitigate the environmental footprint of the food system is to reduce FLW throughout the supply chain as foreseen by target 12.3 of the United Nations Sustainable Development Goals (United Nation, 2015).

The Environment Program of the United Nations (UNEP, 2021) estimated that 17% of the food produced in the world is thrown away; in 2019 this percentage accounted for about 931 million tons of Food Waste (FW), of which 61% from the domestic sector, 26% from food services and 13% from retail services. These estimates are indicative of the magnitude of the FW phenomenon and led to the consideration that if the global amount of FW would correspond to a country, it would be the third largest greenhouse gas emitter, after China and the United States (UNEP, 2021). At the European level, EUROSTAT FW measurements related to 2020 showed that almost 59 million tonnes of fresh food mass were thrown away, corresponding to 10% of the food products available in Europe (Eurostat, 2022).

According to a study carried out by the European Joint Research

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Centre, the reduction of FW would improve the productivity of the agri-food system, bringing benefits in economic terms. In addition, FW reduction would have an important and positive impact on the mitigation of greenhouse gas emissions with an estimated reduction of up to 18 million tons of carbon dioxide equivalent (European Commission. Joint Research Centre, 2023).

Reduction of FW is an essential part of the transformation of the food systems that need to be reshaped to have less impact on the environment (Kennedy et al., 2021). The increased sustainability of food production and consumption was the inspiration principle of the project "Organic agro-food systems as models for sustainable food systems in Europe and Northern Africa" – SysOrg (SysOrg project, 2021). The SysOrg project focuses on territorial food systems investigating the role of different dietary approaches and models, reduction of FW, and enhanced organic food and farming as sustainability elements. The main aim of the project is to identify the critical points within the food system in five selected territories to establish possible common interventions to improve the local food system also with the reduction and prevention of FW. Hence, the SysOrg project mapped and analyzed FW in five territories: North Hessia Federal State (Germany), Cilento Bio-District (Italy), Kenitra Province (Morocco), Warsaw Municipality (Poland), Copenhagen Municipality (Denmark) having specific characteristics and different levels of implementation of FW policies.

Against this background, the main objectives of this study were to measure the quantity, frequency, and typology of household FW in the five territories to evaluate differences and similarities. The data collected had the scope to design recommendations for policy actions aimed at FW prevention and reduction. Specific purposes of the work were the evaluation of the effect of sociodemographic characteristics on household FW, the assessment of consumers' attitudes toward FW, and its relationship with the quantity of waste generated by the families.

2. Theory

The cross-territory analysis of FW, as conceptualized in this study, would offer insights for developing models and inputs aimed at reaching the 12.3 target of the Sustainable Development Goals aimed at substantially reducing waste generation through prevention, reduction, recycling, and reuse (United Nation, 2015). The value of this research is related to the fact that the analysis of FW status and causes in the five territories in five different countries, geographically distributed over Northern, Eastern, Central, and Southern Europe as well as North Africa, contributes to a broad transnational and multi-actor discussion on the FW reduction and prevention measures, with the possibility of transferring the obtained results to other regions as starting or accelerator points for FW reduction. Critical points (barriers and levers) for FW prevention and reduction could be identified and proposed on the basis of the study results. The selected territories (two urban areas and three rural settings) were mapped as far as concerning the programs to fight FW present on the ground and in general regarding their approach to food system sustainability. The analyzed areas have in common initiatives to significantly contribute to FW reduction even at different implementation levels. The two urban territories diverged in terms of policy actions with the Municipality of Copenhagen having several ongoing campaigns supporting the reduction of food waste at the public and private level in the framework of an advanced stage of promotion of sustainability of food choices (City of Copenhagen, 2024). On the other hand, Warsaw is at an early stage of FW management mainly focused on food sharing and donation (Foodsharing Polska, 2024; Foodsi, 2024) in the framework of a dynamic increase of Warsaw consumers' ecological awareness. The three rural areas studied in this research included the North Hessia Federal State and the Cilento Bio-District, both advanced in terms of territorial protection and food waste (Pugliese and Antonelli, 2015; Schmidt et al., 2019) and the Kenitra Province in which FW policy actions are new and still not embedded in the local food system, with recommendations of low environmental impact of food choices not prioritized (Vereinte Nationen, 2014). Therefore, the theoretical hypothesis underlying this work was that food habits, different local cultures, settings, and the level of implementation of FW policies would impact the quantity and typology of food thrown away in the households. A comprehensive assessment of FW in the five territories was carried out including, besides the quantitative dimension, the potential and hypothetical causes of FW.

This study intended to answer the following research questions: i) what is the actual level of waste in the five territories covered by the SysOrg project? ii) which families' characteristics impact FW production? iii) what are the reasons, motivations, or barriers for waste reduction and prevention? iv) it is possible to characterize the patterns of FW in the five territories?

3. Materials and methods

3.1. The survey methodology and the questionnaire

The present study is a cross-sectional assessment conducted by administrating a questionnaire to adult (>18 years old) residents in the above-mentioned five territories. The compilation of the questionnaire was voluntary and anonymous, and the participants were informed about the objectives of the study and the intention to publish the results. Data were collected following the European Commission General Data Protection Regulation (679/2016) and the study was conducted according to the guidelines of the Declaration of Helsinki (World Medical Association, 2018).

The data collection was carried out from January to June 2022. A convenience sample size of a maximum of 500 completed questionnaires per territory was fixed. Respondents were recruited using the "river" sampling methodology (Lehdonvirta et al., 2021), a sampling procedure that was slightly different in the five territories characterized by cultural peculiarities and variable geographical extension (SysOrg project, 2021). In North Hessia, Kenitra, Warsaw, and Copenhagen respondents were recruited via social media channels and questionnaires were completed online using the Lime Survey© data collection tool. In Kenitra, in consideration of the low coverage of internet access (Organisation for Economic Co-operation and Development and United Nations, 2001), the online data collection was coupled with direct face-to-face interviews of randomly selected people in public places. The limited geographical extension and density of the population of the Cilento Bio-District (Cilento Bio-District, 2023) would not permit the recruitment of respondents via social media. Hence the administration of the questionnaire was carried out with the assistance of a specialized research agency, Format Research© S.r.l., Italy. The random selection of respondents was carried out using the municipalities' personal data lists of the Cilento Bio-District residents. The interviews were administered through the *Cati* system (*Computer Assisted Telephone Interview*) or *Cawi* system (*Computer Assisted Web Interview*). A validated questionnaire (Grant et al., 2023; Scalvedi and Rossi, 2021; Van Herpen et al., 2019) aimed to quantify still edible food that was wasted and to evaluate the perception of FW by consumers was used. The final questionnaire and the modalities of translation into the languages of the five territories were reported in Table A1 and Fig. A1 (Appendix A).

3.2. Data analysis

After the data cleaning procedure (Table B1 – Appendix B) that implies the elimination of 2033 units, the final sample consisted of 2154 respondents. Also, the absolute values of income levels in the five territories were different; hence the income variable was categorized into 7 levels from the lowest to the highest.

A descriptive analysis was performed using means and frequencies related to FW.

ANOVA was carried out to investigate per capita FW among the sociodemographic, attitude constructs, and to assess the difference between territories of the most wasted food categories. To understand the strength of the relationship R^2 was calculated according to the following formula:

$$R^2 = 1 - \frac{RSS}{TSS} = 1 - \frac{\sum_{i=1}^{N}(y_i - \widehat{y}_i)^2}{\sum_{i=1}^{N}(y_i - \overline{y})^2} = \frac{\sum_{i=1}^{N}(\widehat{y}_i - \overline{y})^2}{\sum_{i=1}^{N}(y_i - \overline{y})^2} = \frac{ESS}{TSS}$$

Where: *TSS = Total Sum of Squares; RSS = Residual Sum of Square; ESS = Explained Sum of Squares*.

A linear model was applied to evaluate differences in per capita FW among sociodemographic groups and attitudes and to analyze variations of the most wasted food categories between territories. A dichotomic logistic model was used to study the probability of not wasting among sociodemographic variables and attitudes. The model was also used to evaluate the probability of waste in the different waste typologies and for each of the most wasted food categories. The logistic model was defined as follows:

$$\text{logit}(pr\{\pi\}) = \log(\ Odd(pr\{\pi\})\ ) = log\left(\frac{pr\{\pi\}}{1 - pr\{\pi\}}\right) = \beta_o + (\beta x)$$

Where $\pi = \{not\ waste\} = \{Y = no\}$

For each logistic model with factorial explanatory variables (variable X, sociodemographic variables), the probability of not wasting was calculated for each category a of each variable x using the following formula:

$$\Pr\{\pi \mid x = a\} = \frac{Odd(\pi \mid x = a)}{1 + Odd(\pi \mid x = a)} = \frac{\exp\{\beta_0 + \beta_{x=a}\, x\}}{1 + \exp\{\beta_0 + \beta_{x=a}\, x\}}$$

For each logistic model with continuous explanatory variables (variable X, the attitudes), the odds ratio (OR) was calculated to measure the association between the attitudes and the probability of not wasting ($Pr\{\pi\}$):

$$OR = \left(\frac{pr\{\pi \mid X = x+1\}/1 - pr\{\pi \mid X = x+1\}}{pr\{\pi \mid X = x\}/1 - pr\{\pi \mid X = x\}}\right) = \exp\{\ \beta\ \}$$

In the above-described model, the OR represents the effect of a unit increase in the explanatory variable on the probability of not wasting. Specifically, if the other variables remain constant, a unit increase from X = x to X = x + 1 results in a change in logit equal to:

$$logit(\ pr\{\pi \mid X = x+1\}\ ) -\ logit(\ pr\{\pi \mid X = x\}\ ) = log\left(\frac{pr\{\pi \mid X = x+1\}/1 - pr\{\pi \mid X = x+1\}}{pr\{\pi \mid X = x\}/1 - pr\{\pi \mid X = x\}}\right) = [\beta_o + (\beta(x+1))] -\ [\beta_o + (\beta x)] = \beta_o -\ \beta_o + \beta(x+1) -\ (\beta x) = \beta$$

An OR = 1 indicates that the attitude does not impact the odds of not wasting; an OR > 1 indicates direct proportionality between the score (Likert scale) of the behavior variable and the probability of not wasting; an OR < 1 means inverse proportionality among the score of the behavior variable and probability of not wasting.

The Poisson regression model was employed to investigate the difference in waste typologies among territories. The food categories (Y in the formula) thrown away per waste typology were estimated with the following formula:

$$\log(\ Y\ ) = \beta_o + (\beta x)$$

A model-based clustering approach (Seri, 2023) was employed to identify respondents' waste profiles. This clustering approach considers the data as arising from a mixture of distinct probability distributions, each usually corresponding to a distinct cluster. In the current work, a mixture of multivariate normal distributions was used. This type of approach allows for an assessment of uncertainty about the assignment of units to clusters. Each data point is probabilistically assigned to different clusters, allowing for fuzzy and non-rigid classification in waste profiles (Henning et al., 2020; McNicholas, 2016). For this analysis, carried out with the mclust package of R software (Scrucca et al., 2023), the most wasted food groups (in quantity and frequencies) were included as the variables with the highest level of variance. Based on the BIC (Bayesian Information Criterion) (Schwarz, 1978) and ICL (Integrated Complete-data Likelihood) (Biernacki et al., 2000), a 6-component model with EEV (Equal volume, Equal shape, Variable orientation) parametrization was chosen (Celeux and Govaert, 1995). Finally, considering the uncertainty of assignment to the clusters, a logistics model was implemented, using the cluster as the response variable and the territory as the explanatory variable; each unit was weighted with the probability of belonging to the cluster to which it was assigned.

The statistical analysis was performed using R Software, version 4.3.1 (updated on 2023-06-16).

4. Results and discussion

The characteristics of the sample are reported in Table C1 (Appendix C).

4.1. Household FW: quantities, frequency, and waste typologies

Fig. 1 (Panel A) shows the quantitative evaluation of FW in the five territories. Considering only the families that wasted, a mean of 399 g of FW per household per week, equivalent to 153 g per capita per week, was found. The lowest levels of household waste were found in North Hessia (274 g/week), while the highest were found in Kenitra (539 g/week). Family size influenced the total amount of FW, hence normalizing the household FW for the number of family members, the Kenitra Province showed the lowest level of FW (125 g/capita/week). This is related to the fact that Kenitra had the highest percentage of large households (60% with five or more members, data not shown) while in the other territories, this percentage is about 10%. Copenhagen (201 g) and Warsaw (180 g) Municipalities resulted in the highest level of waste expressed as quantity per capita per week. In the present study, the measurement of food waste was performed using questionnaires applying the recall method, a self-reported data collection relying on respondents' memory. Food waste quantification with the questionnaire is an indirect measurement that has been reported to underestimate the amount of food waste (Elimelech et al., 2019). The different methods for measuring food waste (e.g., diaries, waste composition analysis, questionnaires, etc.) have advantages and disadvantages, but any of them is superior to the others (Van Herpen et al., 2016, 2019). For example, waste composition analysis that provides detailed and accurate insights into the level of food waste is an impractical approach for use across

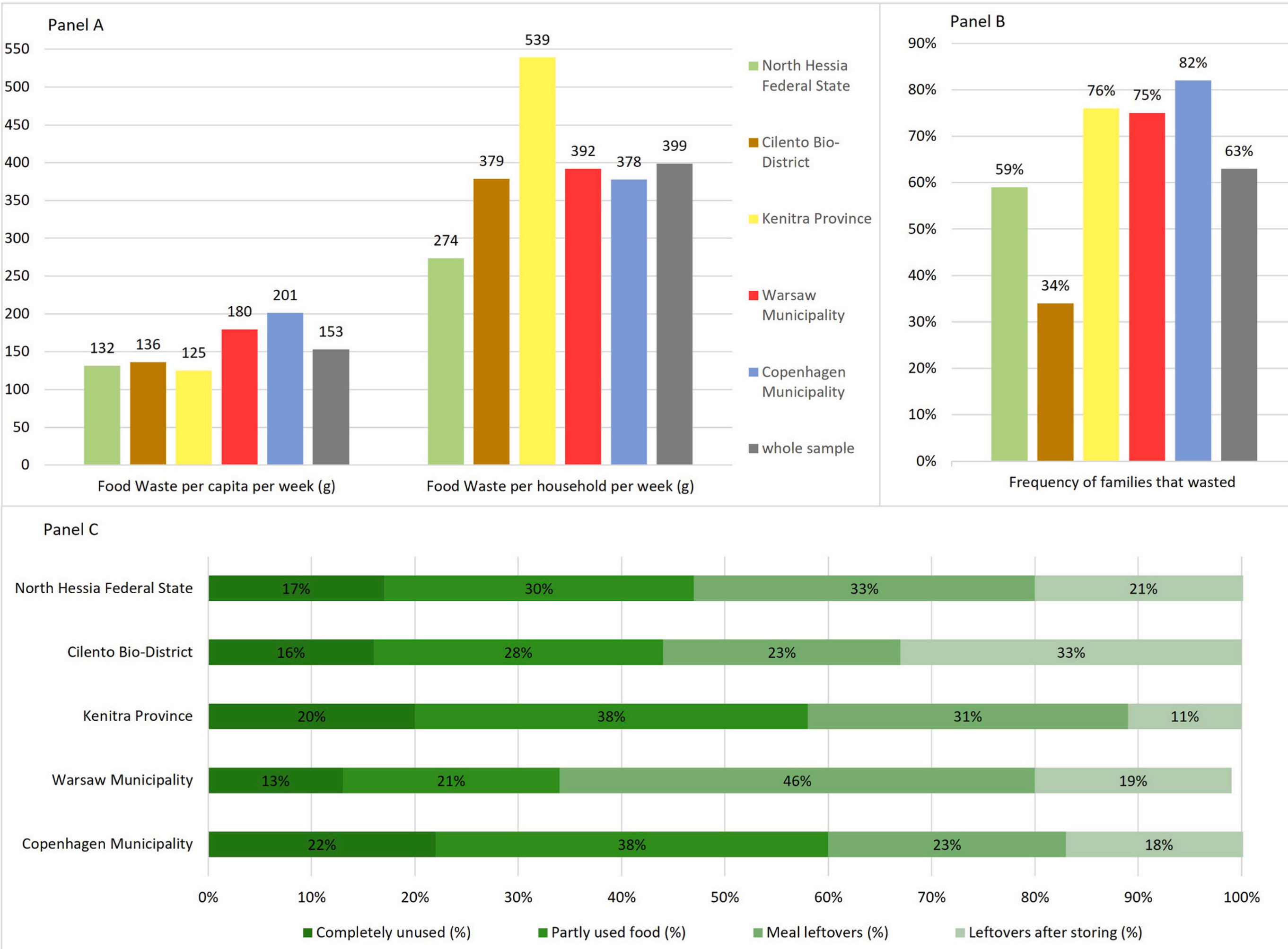

Fig. 1. Average quantities of household food waste per capita and per household per week (calculated for families with food waste >0) (Panel A), frequency of families that wasted (Panel B), and waste typologies (Panel C) in the five territories.

large samples of households (Lebersorger and Schneider, 2011). In this study, the selection of the methodology for food waste assessment was carried out by combining the performance efficiency, the acceptance by respondents, the reliability of the data collected, and, the applicability in large-scale surveys that were possible with questionnaire and not with other approaches for costs and practical reasons (Grant et al., 2023).

As reported in Panel B of Fig. 1, approximately 63% of households reported that they throw away at least one food product belonging to one of the food groups. The highest frequency of FW was observed in Copenhagen Municipality (82%) and the lowest was found in Cilento Bio-District (34%). The households in Cilento Bio-District and Warsaw had the most similar behavior in terms of waste typologies and Copenhagen showed a waste typologies profile similar to the mean of the whole sample (Panel C - Fig. 1). The information about FW typology is important to be taken into consideration when implementing/shaping policies. When food is wasted as partly used or unused food as in Cilento Bio-District (partly, 38%; unused, 20%) and Warsaw (partly, 38%; unused, 22%), preventive actions should focus on the purchase habits and pantry or fridge organization. On the other hand, when food is mainly wasted as meal leftovers or stored leftovers as in Kenitra (meal leftover, 46%; stored leftover, 19%) and North Hessia (meal leftovers, 23%; stored leftover 33%), the policy actions should focus on the kitchen's abilities and the capacity to evaluate the food quantities to cook.

The five territories showed differences in terms of typologies of generated food waste (Table 1), with Kenitra Province characterized by the higher frequency of generating each waste typology when compared to other territories. FW as completely unused had the lowest probability of occurring in the Cilento Bio–District (15%), while FW as partly used had the highest probability of occurring in Copenhagen and Warsaw Municipalities (both 52%). The probability of throwing away meal leftovers was significantly higher in Kenitra (62%) than in other territories, while waste leftovers after storage had a lower probability of occurrence in the Cilento Bio-District (9%) than in other territories.

4.2. *Household FW and sociodemographic variables: quantities and the probability of not wasting*

The investigation of the relationship between sociodemographic variables and the quantity of per capita FW as well as the probability of not wasting permitted to answer the research question related to the identification of families' characteristics that impact FW generation. As reported in Table 2, the number of family members is the characteristic most strongly linked with the quantity of waste produced in the household (the family size explained almost 13% of the variability of waste) while age and level of education were not associated with FW. Belonging to different territories has a small but significant effect on the quantity of FW (the variable territory explained more than 2% of the variance of waste) as household income which explains slightly more than 1% of the variance of waste.

The linear models (Table 2) confirmed these results with the family

Table 1
Analysis of typology of waste among 5 territories. Generalized Linear Models (Poisson model and dichotomic logistic model); significant p-value <0.05.

Waste typology	Category	Poisson-model estimation	Wald-test p-value	logit estimation (probability waste in the typology)	Wald-test p-value
Completely unused	North Hessia Federal State*	**1.23**	0.0146	22%	0.0000
	Cilento Bio-District	1.89	0.0003	**15%**	0.0029
	Kenitra Province	**2.46**	0.0000	23%	0.6986
	Warsaw Municipality	1.55	0.0296	34%	0.0000
	Copenhagen Municipality	**1.25**	0.8986	34%	0.0003
Partly used	North Hessia Federal State*	1.56	0.0000	29%	0.0000
	Cilento Bio-District	2.33	0.0000	22%	0.0098
	Kenitra Province	**2.41**	0.0000	37%	0.0121
	Warsaw Municipality	1.80	0.0760	**52%**	0.0000
	Copenhagen Municipality	1.85	0.0537	**52%**	0.0000
Meal leftovers	North Hessia Federal State*	1.88	0.0000	20%	0.0000
	Cilento Bio-District	2.21	0.0919	20%	0.7645
	Kenitra Province	**3.19**	0.0000	**62%**	0.0000
	Warsaw Municipality	1.74	0.4490	32%	0.0001
	Copenhagen Municipality	2.02	0.4552	39%	0.0000
Leftovers after storing	North Hessia Federal State*	1.78	0.0000	31%	0.0000
	Cilento Bio-District	1.64	0.5276	**9%**	0.0000
	Kenitra Province	**2.41**	0.0001	34%	0.2717
	Warsaw Municipality	1.67	0.4953	27%	0.1959
	Copenhagen Municipality	1.63	0.3791	39%	0.0166

*intercept

size being the variable with the strongest association with per capita waste meaning that at the increase of the number of household members, a corresponding decrease of per capita waste was observed. This finding was also reported in other studies that stressed the importance of the packaging size, often not designed to meet the consumer needs of smaller households, as one of the reasons for the high FW in these families (Williams et al., 2020). The models demonstrated a specific effect of the territories on FW with the polarization of North Hessia, Cilento Bio-District, and Kenitra wasting about 130 g/capita/week, and Warsaw and Copenhagen Municipalities wasting approximately 190 g/capita/week. This finding could be explained by considering that consumers in rural areas had more efficient still edible FW management than urban areas (Grant et al., 2023; Secondi et al., 2015).

According to Table 2, the probability of not wasting decreases progressively as the number of household members increases, with smaller families having a higher probability of not wasting (41% for single-member families and 47% for two-member families) compared to larger families (29% for four-member families and 27% for 5 or more members). Hence, larger households are more likely to waste but waste less in terms of per capita quantities. This data could be interpreted considering that larger families while being more efficient in food utilization (Parizeau et al., 2015), were potentially at higher risk of generating waste in consideration of their large food needs. In addition, in larger households, there may be a tendency to over-purchase leading to potential waste when products are unused or expire before they can be consumed (Babbitt et al., 2021). Territorial belongings significantly influence the probability of not wasting which was higher in Cilento Bio-District (66%), followed by North Hessia (41%), and lowest in the other three territories with the minimum in Copenhagen Municipality (18%). The probability of not wasting decreased as the income increased, being 47% and 36% for the two lowest income levels up to 28% and 23% for the highest income levels. According to the available literature, the effects of income on FW level were not univocal, with some studies demonstrating that the lowest was the income the highest was the FW (Stancu et al., 2016), others reporting the opposite (Stefan et al., 2013; Szabó-Bódi et al., 2018), and others not showing any relation between FW and income (Koivupuro et al., 2012; Qi and Roe, 2016). As commonly reported (Grant et al., 2023; Grasso et al., 2019), older people (50% for 55–64 years and 70% for >65 years) have a higher probability of not wasting than the youngest (about 27 % for 18–34 years and 35–44 years).

4.3. Household FW and consumers' FW attitudes: quantities and the probability of not wasting

The set of constructs related to the reasons for waste was more related to the quantity of household FW than the set of constructs related to the consequences of waste (Table 3). Among the reasons for waste, seven constructs out of eleven significantly explained different percentages of variance with the claim "I do not have difficulties and avoid FW" showing the highest proportion of explained variance (3%). For the other constructs, this percentage is about 1. Among the set of FW consequences, the concern for the future generation was the only construct that significantly explained 1% of the variability.

The consideration of the effects of waste on future generation resulted in a β equal to −20 meaning that each score of increasing of the Likert scale of this construct corresponded to a decrease of 20 g of per capita FW. For the construct of the consequences of waste for "food availability in the world," each score of increasing on the Likert scale corresponded to a decrease of 12 g of household FW. The claim "does not have large adverse effects", which might be assumed to be related to the quantity of FW, resulted in no significant effects. Concerning the set of constructs related to the reasons for waste, the declared capacity to avoid FW ("I do not have difficulties and avoid FW") determined a reduction of 29 g of FW at each point of the increase of Likert scale indicating a correct self-perception of food waste management. Difficulties in reusing leftovers were also related to FW, with β equal to 17 for "it is difficult to use leftovers to prepare new dishes" and a β corresponding to 15 for "it is difficult to reuse leftovers from meals only when their quantity is small" indicating an increasing of FW for each point of increasing of the Likert scale. $\beta > 10$ resulted in the construct "I usually leave food in the fridge for too long because I don't know how to cook it" ($\beta = 13$), "it is difficult to prepare a meal with the food I usually have at home" ($\beta = 13$), and "I rather waste leftovers from meals to avoid spoilage" ($\beta = 10$). Other constructs such as "I do not have enough capacity in my kitchen to store food leftovers", "I like to prepare meals of fresh food instead of leftovers for tasty reasons" and "I avoid storing food leftovers because it ends up as waste anyway in a while" resulted with a significative β lower than 10.

In Table 3 the results of the dichotomous logistic models for the study of the probability of not wasting (ORs) were reported. The construct "consequence of waste for future generations" showed a significant result with an OR less than 1 (OR = 0.92), which means that as the Likert scale

Table 2
Relationship between the quantity of food waste and sociodemographic variables. ANOVA and Generalized Linear Models (linear model and dichotomic logistic model); significant p-value <0.05.

ANOVA			GENERALIZED LINEAR MODELS				
Var	R^2 (variance explained by the variable)	F-test p-value	Response options	lm estimation	*t*-test p-value	logit estimation (probability of not wasting)	Wald -test p-value
Territory	0.021	0.00001	North Hessia Federal State*	**131.63**	**0.0000**	**41%**	**0.0000**
			Cilento Bio-District	**4.39**	**0.8207**	**66%**	**0.0000**
			Kenitra Province	**−6.32**	**0.6925**	**24%**	**0.0000**
			Warsaw Municipality	**47.91**	**0.0032**	**25%**	**0.0000**
			Copenhagen Municipality	**69.41**	**0.0001**	**18%**	**0.0000**
Age	0.003	0.38630	18-34*	152.88	0.0000	**27%**	**0.0000**
			35–44	−10.83	0.4515	26%	0.8446
			45–54	−3.24	0.8366	35%	0.0077
			55–64	29.18	0.1145	50%	0.0000
			≥65	−0.73	0.9760	**70%**	**0.0000**
Sex	0.009	0.00201	Female*	167.74	0.0000	33%	0.0000
			Male	−38.83	0.0007	43%	0.0000
			Not specified	36.04	0.5129	30%	0.7865
Education	0.006	0.32284	1 - No formal education*	124.70	0.0123	32%	0.0787
			2 - Primary education	3.12	0.9582	51%	0.0965
			3 - Lower secondary education	−4.93	0.9261	59%	0.0108
			4 - Upper secondary education	16.43	0.7506	46%	0.1804
			5 – Apprenticeship	13.49	0.8028	35%	0.7410
			6 - Bachelor's degree or equivalent level	41.07	0.4209	25%	0.4364
			7 - Master's degree or equivalent level	35.52	0.4829	29%	0.7732
			8 - Doctoral studies (PhD) and/or higher	50.80	0.3506	34%	0.8573
Family size	**0.128**	0.00000	1*	**308.91**	**0.0000**	**41%**	**0.0010**
			2	**−155.78**	**0.0000**	47%	0.0745
			3	**−158.18**	**0.0000**	36%	0.1467
			4	**−201.57**	**0.0000**	29%	0.0001
			≥5	**−223.98**	**0.0000**	**27%**	**0.0000**
Household income	0.012	0.02134	a - lower level*	180.47	0.0000	**47%**	**0.3542**
			b - low level	−46.79	0.0325	36%	0.0042
			c - medium-low level	−13.58	0.5592	32%	0.0004
			d - medium level	17.96	0.4833	32%	0.0025
			e – medium high-level	−30.34	0.2148	26%	0.0000
			f - high level	−31.62	0.2212	28%	0.0001
			g - highest level	−17.83	0.4129	**23%**	**0.0000**
			I prefer not to answer	−54.09	0.0067	48%	0.9584
Household income used for food (%)	0.007	0.02983	<10%*	149.11	0.0000	40%	0.0028
			10–25%	18.33	0.3242	39%	0.5914
			26–50%	−19.95	0.3141	33%	0.0433
			>50%	2.44	0.9250	36%	0.3841

*intercept

score increases, the probability of not wasting decreases. All the constructs relative to the reasons for waste had a large significant effect. The majority of the observed ORs are around 0.7 meaning that as the variables' scores increase, the probability of waste increases too. Among those it should be pointed out the ORs related to the variables related to the difficulty of reusing leftovers: "It is difficult to use leftovers to prepare new dishes" (OR = 0.61), "It is difficult to reuse leftovers from meals only when their quantity is small" (OR = 0.62) and "my household members do not like to eat the same kind of food in a row" (OR = 0.65). OR >1 was observed only for the construct "I do not have difficulties and avoid FW" which confirms its predictable effect in limiting FW (OR = 1.36).

These results were particularly relevant to answering the research question on the reasons, motivations, or barriers to waste reduction and prevention. Difficulties in managing meal leftovers and inability to kitchen food management had the greatest influence on FW probably because of the limited capacity to reuse leftovers and invent new dishes with the food available at home (Ishangulyyev et al., 2019) or for effect of limited knowledge of how to properly store remaining foods which induces to buy fresh food (Gojard et al., 2021). These aspects were found also in the studies of Romani et al. (2018) and Stancu et al. (2016), showing that the appropriate planning of meals had a positive effect on avoiding FW. On the other hand, both the difficulty in reusing leftovers (Bravi et al., 2020) and the concern related to leftover safety significantly influence the production of FW (Hebrok and Boks, 2017).

4.4. *Household FW among food categories*

As reported in Fig. 2, fresh products (bread, fresh fruit and vegetables, and nonalcoholic beverages, that include milk) were the most wasted food categories both in frequencies and quantities. These findings are in line with the consideration that the perishability of the

Table 3
Relationship between the quantity of waste and (a) the perceived consequences and (b) the reported reasons for food waste. ANOVA and Generalized Linear Models (linear model and dichotomic logistic model); significant p-value <0.05.

Set of questions	ANOVA: Var	ANOVA: R^2 (variance explained by Var)	ANOVA: F-test p-value	GENERALIZED LINEAR MODELS: lm estimation		t-test p-value	logit estimation (probability of not waste)		Wald -test p-value
consequences of food waste	Environment	0.003	0.09142	195.32	(*)	0.0000	0.50	(#)	0.0003
				−9.79	(β)	0.0601	1.04	(OR)	0.3592
	future generations	**0.009**	**0.00969**	237.73	(*)	0.0000	0.86	(#)	0.4105
				−19.74	**(β)**	**0.0004**	**0.92**	**(OR)**	**0.0412**
	poor vulnerable people	0.000	0.46274	156.43	(*)	0.0000	0.69	(#)	0.0140
				−0.85	(β)	0.8525	0.96	(OR)	0.2504
	food availability in the world	0.004	0.17218	202.27	(*)	0.0000	0.51	(#)	0.0002
				−11.86	(β)	0.0208	1.04	(OR)	0.4051
	economic consequences for my family	0.000	0.67711	143.80	(*)	0.0000	0.58	(#)	0.0003
				2.37	(β)	0.6003	1.00	(OR)	0.9005
	does not have large adverse effects	**0.000**	**0.13694**	159.27	(*)	0.0000	0.56	(#)	0.00000
				−2.51	**(β)**	**0.5154**	**1.02**	**(OR)**	**0.5340**
reasons for food waste	it is difficult to prepare a meal with the food I usually have at home	0.006	0.02607	125.98	(*)	0.0000	1.12	(#)	0.2125
				12.80	**(β)**	**0.0039**	0.71	(OR)	0.0000
	it is difficult to use leftovers to prepare new dishes	**0.012**	**0.00076**	112.04	(*)	0.0000	1.65	(#)	0.0000
				16.55	**(β)**	**0.0000**	**0.61**	**(OR)**	**0.0000**
	it is difficult to cook anything other than the recipes I know	0.002	0.25219	139.35	(*)	0.00000	1.17	(#)	0.0767
				5.99	(β)	0.1520	0.71	(OR)	0.0000
	I usually leave food in the fridge for too long because I don't know how to cook it	0.007	0.04359	125.72	(*)	0.0000	1.11	(#)	0.2395
				13.12	**(β)**	**0.0020**	0.71	(OR)	0.0000
	it is difficult to reuse leftovers from meals only when their quantity is small	**0.010**	**0.00005**	113.36	(*)	0.0000	1.70	(#)	0.0000
				14.91	**(β)**	**0.0002**	**0.62**	**(OR)**	**0.0000**
	my household members do not like to eat the same kind of food in a row	0.001	0.12760	141.56	(*)	0.0000	1.59	(#)	0.0000
				4.22	(β)	0.2713	**0.65**	**(OR)**	**0.0000**
	I rather waste leftovers from meals in order to avoid spoilage	0.005	0.08619	127.96	(*)	0.0000	1.13	(#)	0.1655
				10.24	(β)	0.0104	0.74	(OR)	0.0000
	I like to prepare meals of fresh food instead of leftovers for tasty reasons	0.004	0.04716	128.28	(*)	0.0000	1.28	(#)	0.0076
				9.24	(β)	0.0201	0.72	(OR)	0.0000
	I do not have enough capacity in my kitchen to store food leftovers	0.004	0.11118	132.10	(*)	0.0000	1.11	(#)	0.2308
				9.52	(β)	0.0249	0.72	(OR)	0.0000
	I avoid storing food leftovers because they end up as waste anyway in a while	0.003	0.02333	135.15	(*)	0.00000	1.26	(#)	0.0073
				7.58	(β)	0.0574	0.69	(OR)	0.0000
	I do not have difficulties and avoid food waste	**0.029**	**0.00000**	265.90	(*)	0.0000	0.17	(#)	0.0000
				−29.43	**(β)**	**0.0000**	**1.36**	**(OR)**	**0.0000**

* = intercept; β = regression coefficient; # = exp{intercept}; OR = Odd Ratio = exp{β}

products is an important determinant of waste (Grant et al., 2023; Herzberg et al., 2020; Ilakovac et al., 2020; Williams et al., 2020).

In Table 4 the seven most wasted food groups (considering quantity and frequency) were analyzed as far as the quantity of waste and the probability of being thrown away. Cilento Bio-District and Copenhagen Municipality were the opposite in the probability of wasting fresh vegetables, with the largest range of difference. Fresh fruit was significantly more wasted in Copenhagen (100 g) and Warsaw municipalities (87 g) and less in Kenitra Province (23 g). Bread was more wasted in Copenhagen (118 g), while Cilento Bio-District (57 g) and North Hessia Federal State (43 g) showed lower waste levels of this food group, both in quantities and probability. North Hessia (176 g) and Copenhagen (197 g) showed the highest values of waste for non-alcoholic beverages, while Kenitra (54 g) recorded the lowest. Finally, alcoholic beverages were most wasted in North Hessia (222 g). Eating behaviors and food consumption patterns were previously shown to be related to FW (Hermanussen et al., 2022), and besides the reported findings that fresh foods were the most wasted (Helander et al., 2021), specific food waste data were peculiar to the different territories.

4.5. Household FW profiles (clusters)

Using the model-based cluster, six clusters corresponding to definite FW profiles were identified. In terms of FW quantities, two profiles (clusters 1 and 2) had much higher overall levels of FW than the others (clusters 3 to 6) (Table 5).

In detail, Cluster 1 was characterized by the highest level of waste (870 g per capita per week) and identified extreme behaviors in fact the probability of belonging to this cluster is very low (<1%). Only 7 households were included in this cluster with an uncertainty close to 0%. Cluster 2 was characterized by a high level of waste (291 g per capita per week), especially of fresh products (fruit, bread, non-alcoholic beverages -including milk- and fresh vegetables). Few respondents belonged to this cluster (about 3% of the whole sample, data not shown), with a higher prevalence from Kenitra Province (5%) and Copenhagen Municipality (6%). The uncertainty of assignment to this cluster is low (5%). Cluster 3 showed on average 77 g per capita per week of waste mostly characterized by alcoholic and non-alcoholic beverages. Cluster 3 included about 5% (data not shown) of the respondents with a higher prevalence of households from Copenhagen (8%) and a lower prevalence from Warsaw Municipality (almost 2%) The characteristics of this cluster correspond to a very particular behavior resulting in a low uncertainty of assignment (2%). Cluster 4 showed on average 60 g per capita per week of waste mostly characterized by bread and fresh vegetables. This is a common behavior hence this cluster had the highest average probability of belonging. Cluster 4 included almost 25% of households (data not shown) with the highest prevalence of respondents from Kenitra Province (38%) and Copenhagen (32%). Cilento Bio-District households were less represented (9%). Being a large cluster, the uncertainty of assignment to this cluster is high (37%). Cluster 5 had one of the lowest levels of waste (47 g per capita per week); the food groups most wasted in this cluster were fresh products, such as fruit, and vegetables, but also soups. As cluster 4, also cluster 5 had one of the highest average probabilities of belonging. Almost 60% (data not

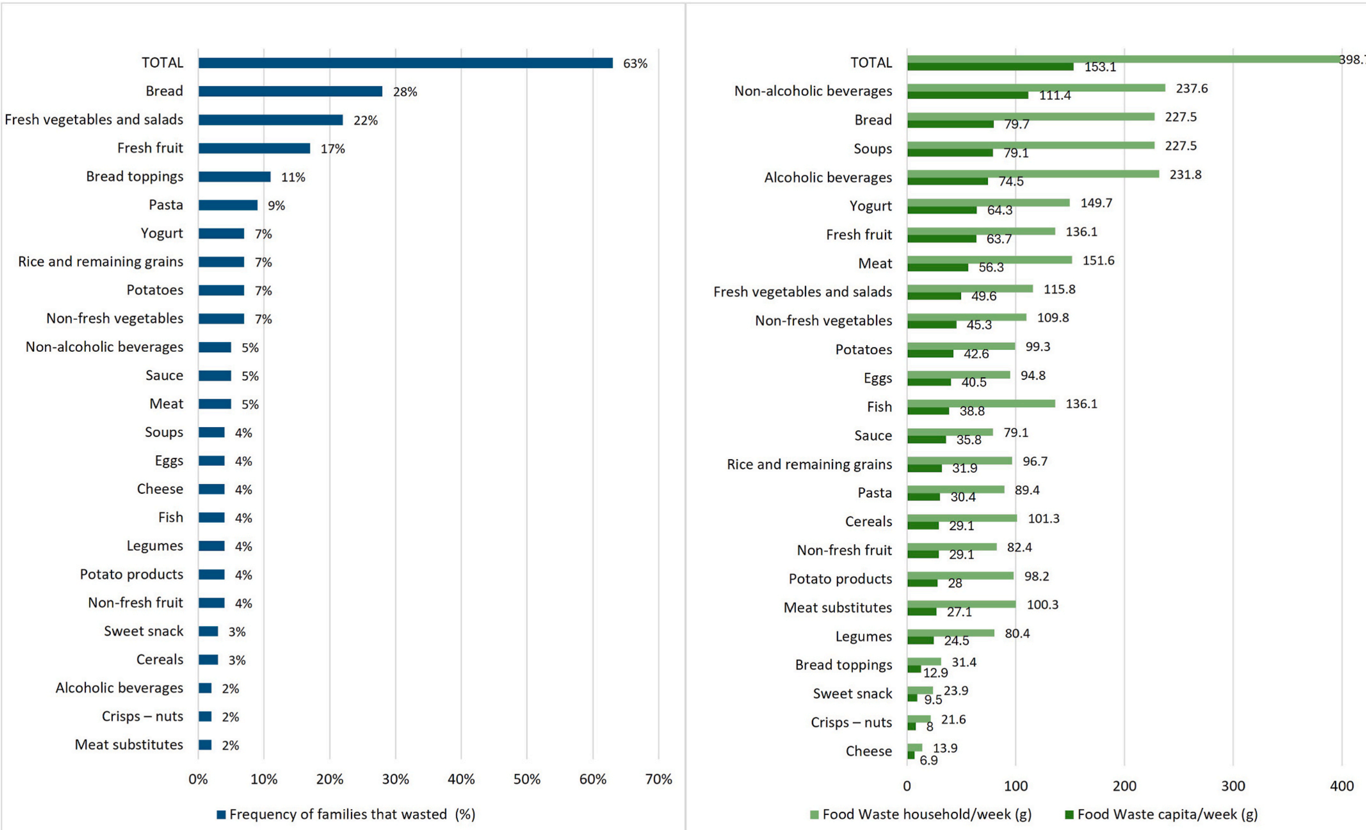

Fig. 2. Food waste per food category: frequencies (%) of families that wasted and average quantities (grams/week, calculated for families with food waste >0).

shown) of the sample belonged to this cluster which included mainly respondents from Cilento Bio-District (81%) and North Hessia Federal State (65%) while the other territories have a prevalence of around 45%. Being so large, the uncertainty of assignment to this cluster is high (60%). Cluster 6 had one of the lowest levels of waste (46.5 g per capita per week); the food groups most wasted in this cluster were bread and yogurt. The average probability of belonging to this cluster is high at a similar extent to the other large clusters (e.g., 5 and 4); however, only 8% (data not shown) of the sample belonged to this cluster. In this cluster, a higher prevalence of respondents from Warsaw (14%) and Copenhagen (10%) was found. The assignment to this cluster occurred with a relatively low level of uncertainty (approximately 16%).

4.6. Household FW profiles among 5 territories

The weighted logistic model was used to study the probability of belonging to the clusters in the 5 territories (Table 6). For the whole sample, Cluster 5 represented the cluster with the highest possibility of belonging (Prob = 44%), followed by Cluster 4 having a 28% probability of belonging; the other clusters had a probability of belonging ranging from 12% (Cluster 6) to 1% (Cluster 1).

Territories varied in terms of probabilities of clusters belonging. North Hessia Federal State showed probabilities of belonging to the clusters similar to the whole sample except for Cluster 5 (OR = 1.3) which was the cluster with the highest probability in this territory (Prob = 51%). The OR > 1 indicated that, with respect to the whole sample, in North Hessia there was a higher probability of having a FW profile characterized by a low level of FW that mainly included fresh foods.

Another territory quite similar to the waste profile of the whole sample was the Copenhagen Municipality. Cluster 5 and Cluster 4 had the highest probabilities of belonging in this territory (respectively Prob = 33% and Prob = 32%). On the other hand, the OR = 0.6 indicated that, in comparison with the other territories, Copenhagen showed one of the significantly lowest probabilities of belonging to cluster 5.

In comparison with the whole sample, the Warsaw Municipality showed differences in the probabilities of belonging to Cluster 6 (20%, the highest probability for this cluster, OR = 1.9) and Cluster 3 (3%, the lowest probability for this cluster, OR = 0.3). Cluster 5 and Cluster 4 were the clusters with the highest probability of belonging to Warsaw (Prob = 41% and Prob = 31% respectively).

Cilento Bio-District differed from the waste profile of the whole sample concerning the very high probability of belonging to Cluster 5 (Prob = 66%, the highest probability for this cluster, OR = 2.5). With respect to the whole sample, Cilento Bio-District had the lowest probability of belonging to Cluster 4 (Prob = 12% OR = 0.3) and Cluster 2 (Prob = 3%, OR = 0.5).

Kenitra Province territory showed the most different waste profiles with respect to the whole sample. Kenitra was the only territory in which cluster 5 did not show the highest probability of belonging (Prob = 30%) that was found for cluster 4 (Prob = 44%). Compared to other territories, Kenitra had the highest probability of belonging to Cluster 4 (OR = 1.9) and Cluster 2 (Prob = 10% OR = 1.6) and the lowest for Cluster 5 (OR = 0.5) and Cluster 6 (Prob = 6% OR = 0.4).

The analysis of the probability of belonging to the clusters in the 5 territories permitted to address the theoretical hypothesis underlying this study and to answer the research question related to the possibility of identifying FW patterns in the five territories. Territories showed differences and similarities both in terms of behaviors and in terms of the quantity of food thrown away that reflected food consumption and dietary habits (Iori et al., 2022). Similar waste behaviors were observed in North Hessia and Cilento Bio-District characterized by the highest probability of having a low level of waste, throwing away mainly fresh foods (cluster 5), and the lowest probability of having medium total waste throwing away mainly bread and vegetables (cluster 4). Kenitra

Table 4
Analysis of food group waste among 5 territories. ANOVA and Generalized Linear Models (linear model and dichotomic logistic model); significant p-value <0.05.

	ANOVA		GENERALIZED LINEAR MODELS				
Food group	R^2 (variance explained by the variable)	F-test p-value	Territory	lm estimation	*t*-test p-value	logit estimation (probability of waste)	Wald-test p-value
Fresh vegetables and salads	0.091	0.00	North Hessia Federal State*	57.84	0.0000	0.19	0.0000
			Cilento Bio-District	−11.25	0.1960	**0.09**	0.0000
			Kenitra Province	−34.57	0.0000	0.22	0.3549
			Warsaw Municipality	9.52	0.1529	0.28	0.0011
			Copenhagen Municipality	−3.36	0.6198	**0.41**	0.0000
Fresh fruit	0.095	0.000	North Hessia Federal State*	56.48	0.0000	0.20	0.0000
			Cilento Bio-District	−15.70	0.2550	0.10	0.0000
			Kenitra Province	**−33.69**	0.0224	0.09	0.0000
			Warsaw Municipality	**30.55**	0.0053	0.25	0.1071
			Copenhagen Municipality	**43.32**	0.0005	0.25	0.1714
Bread	0.033	0.000	North Hessia Federal State*	**43.46**	0.0002	**0.25**	0.0000
			Cilento Bio-District	**13.32**	0.5465	**0.10**	0.0000
			Kenitra Province	48.29	0.0021	0.38	0.0000
			Warsaw Municipality	38.66	0.0150	0.37	0.0001
			Copenhagen Municipality	**74.36**	0.0000	0.38	0.0002
Yoghurt	0.004	0.965	North Hessia Federal State*	81.13	0.0000	0.06	0.0000
			Cilento Bio-District	−7.35	0.7801	0.05	0.5589
			Kenitra Province	−26.66	0.4837	**0.02**	0.0024
			Warsaw Municipality	−10.45	0.6379	0.14	0.0002
			Copenhagen Municipality	−11.91	0.6419	0.11	0.0185
Soups	0.044	0.474	North Hessia Federal State*	109.41	0.0005	0.03	0.0000
			Cilento Bio-District	−45.25	0.3110	0.03	0.7564
			Kenitra Province	−32.67	0.4557	0.03	0.8112
			Warsaw Municipality	29.48	0.4936	0.04	0.5928
			Copenhagen Municipality	−4.02	0.9206	**0.08**	0.0049
Non-alcoholic beverages	0.156	0.002	North Hessia Federal State*	**175.54**	0.0000	0.05	0.0000
			Cilento Bio-District	−93.50	0.0352	0.03	0.1041
			Kenitra Province	**−121.31**	0.0038	0.05	0.5993
			Warsaw Municipality	−82.74	0.0806	0.03	0.0988
			Copenhagen Municipality	**21.88**	0.5603	**0.10**	0.0094
Alcoholic beverages	0.235	0.024	North Hessia Federal State*	**221.88**	0.0000	0.02	0.0000
			Cilento Bio-District	−133.70	0.0055	0.03	0.0946
			Kenitra Province	−149.16	0.0027	0.03	0.1056
			Warsaw Municipality	**−190.63**	0.0273	0.00	0.1267
			Copenhagen Municipality	−125.00	0.0337	0.02	0.5125

*intercept

Province and Copenhagen Municipality have in common the highest probability of having a high total waste (cluster 2) and the lowest probability of having a low level of waste and throwing away mainly fresh foods (cluster 5). These territories have also a high probability of having medium total waste with bread and vegetables most wasted (cluster 4). Warsaw and Copenhagen Municipalities showed the highest probability of having low total waste, with bread, and yogurt as the most wasted foods (cluster 6) and had a similar probability of having medium total waste with bread and vegetables, as the most wasted foods (cluster 4).

The observed similarities could be interpreted also considering the nature of the territories. North Hessia and Cilento Bio-District are both rural areas in which the management of still-edible food is more efficient than in urban settings preventing the occurrence of FW (Liu et al., 2023). What is new and unexpected is the similarity, from the point of view of waste profiles, between two culturally different territories such as Kenitra and Copenhagen.

5. Conclusions, limitations, and future research

The present research indicated significant regional disparities in household FW, with the lowest levels found in North Hessia and the highest in Kenitra. Rural communities, such as North Hessia and Cilento Bio-District, showed more effective household FW practices compared to

Table 5
Results of Model-Based Cluster analysis for Food Waste (FW) profile identification based on most wasted food categories (in quantity and frequencies).

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Centroids (FW g/capita/week)						
Fresh vegetables and salads	**30.06**	**30.61**	5.59	**15.49**	**15.06**	3.40
Fresh fruit	**38.69**	**109.45**	2.00	0.35	**17.86**	9.18
Bread	**183.57**	**95.15**	5.73	**42.38**	1.53	**20.62**
Yogurt	**204.76**	4.00	1.68	0.80	2.34	**13.04**
Soups	**107.14**	6.23	0.04	2.04	**10.07**	0.09
Non-alcoholic beverages	**202.38**	**37.93**	**44.22**	0.59	0.00	0.09
Alcoholic beverages	**103.57**	7.92	**17.59**	0.00	0.18	0.11
TOTAL	**870.18**	**291.28**	76.86	61.64	47.04	46.54
Cluster proportions						
Average probability of belonging	0.3%	3.4%	10.5%	30.5%	27.7%	27.6%
Classification frequencies	7	75	103	521	1286	162
Classification uncertainty	0.00	0.05	0.02	0.37	0.60	0.16
Row percentages of classification						
North Hessia Federal State	0.8%	2.9%	5.1%	**20.3%**	**64.5%**	6.4%
Cilento Bio – District	0.2%	1.4%	4.0%	8.8%	**81.1%**	4.6%
Kenitra Province	0.0%	5.2%	6.3%	**38.2%**	**46.4%**	3.8%
Warsaw Municipality	0.0%	3.3%	1.9%	**27.5%**	**53.1%**	**14.3%**
Copenhagen Municipality	0.7%	5.9%	7.7%	**32.1%**	**43.2%**	**10.3%**

Cluster 1 – Highest total waste, all the food groups wasted
Cluster 2 – High total waste, fruit, and bread most wasted foods
Cluster 3 – Medium total waste, beverages most wasted foods
Cluster 4 – Medium total waste, bread, and vegetables most wasted foods
Cluster 5 – Low total waste, fresh foods most wasted foods
Cluster 6 – Low total waste, bread, and yogurt most wasted foods

Table 6
Probabilities of belonging to waste profiles resulting from cluster analysis among the five analyzed territories. Weighted Logistic Models. (OR = Odd Ratio; Prob = Probability).

cluster waste profile		Whole sample		North Hessia Federal State			Cilento Bio-District		
	Prob	Odd	p-value	Prob	OR	p-value	Prob	OR	p-value
1	0.6%	0.006	0.0000	1.5%	2.504	0.1454	0.5%	0.792	0.8282
2	6.2%	0.066	0.0000	5.1%	0.822	0.5169	3.0%	**0.465**	**0.0721**
3	8.8%	0.096	0.0000	9.7%	1.121	0.6207	9.5%	1.093	0.7302
4	**28.4%**	0.397	0.0000	22.8%	0.744	0.0649	12.0%	**0.342**	**0.0000**
5	**44.3%**	0.794	0.0001	**51.0%**	1.314	0.0454	**66.1%**	**2.457**	**0.0000**
6	11.8%	0.133	0.0000	9.8%	0.812	0.3577	9.0%	0.739	0.2437
cluster waste profile	Kenitra Province			Warsaw Municipality			Copenhagen Municipality		
	Prob	OR	p-value	Prob	OR	p-value	Prob	OR	p-value
1	0.0%	0.000	0.9926	0.0%	0.000	0.9924	1.1%	1.836	0.4508
2	9.5%	**1.594**	**0.0632**	5.2%	0.832	0.5463	8.4%	1.389	0.2646
3	11.0%	1.289	0.2711	3.1%	**0.331**	**0.0032**	11.6%	1.370	0.2160
4	**43.6%**	**1.948**	**0.0000**	**30.5%**	1.104	0.5078	**32.3%**	1.204	0.2795
5	**30.2%**	**0.546**	**0.0001**	**41.0%**	0.875	0.3381	**32.6%**	**0.608**	**0.0033**
6	5.6%	**0.447**	**0.0062**	20.2%	**1.905**	**0.0003**	14.0%	1.217	0.4006

Cluster 1 – Highest total waste, all the food groups were wasted
Cluster 2 – High total waste, fruit, and bread most wasted foods
Cluster 3 – Medium total waste, beverages most wasted foods
Cluster 4 – Medium total waste, bread, and vegetables most wasted foods
Cluster 5 – Low total waste, fresh foods most wasted foods
Cluster 6 – Low total waste, bread, and yogurt most wasted foods

urban areas. Family size was identified as a significant factor in FW generation with larger families characterized by a lower FW per capita compared to smaller families. The study highlighted that the consideration of the effects of waste on future generations seems to serve as a motivating factor for reducing waste while difficulties in reusing leftovers and managing food were identified as major barriers to waste prevention. In conclusion, the study underscores the need for tailored strategies to reduce FW, considering regional differences, household composition, and the impact of policies and awareness campaigns. Efforts to minimize FW should focus on promoting responsible consumption and better food management practices, especially in urban areas.

The scientific added value of the paper is related to its comprehensive analysis of FW across five distinct territories, spanning five different countries. This geographical diversity and the approach used are valuable in the sense that the findings could contribute to the exploration of varied perspectives and experiences regarding FW management and reduction strategies. Moreover, the potential to transfer the findings of this analysis to other regions is substantial also considering that the results obtained from these territories can serve as starting points or accelerators for FW reduction efforts elsewhere. Critical factors, either obstacles or facilitators, that influence FW prevention and reduction, were identified, and could be used for proposing targeted and effective strategies to mitigate FW at local and regional scales. providing actionable knowledge with broader applicability and potential impact.

This study has limitations and strengths. The most important limitation was the sampling methodology which was a non-probabilistic assessment, the "river" sampling methodology that, permitted to reach many participants at limited costs. With this methodology, results were not generalizable to the whole population of the target territories, but the outcome could be used to describe and compare the data in the different areas in coherence with the objectives of the present study. Another limitation of this work was that the measurements were carried out with the use of a questionnaire that relies on respondents' memory (one week recall) and subjective evaluation of the FW. However, this methodology has the advantages of combining feasibility, acceptance by respondents, and reliability of the data collected minimizing the costs. In addition, the questionnaire used in the present study was a validated tool that facilitated the comparability with other assessments.

The most important strength of the research is the coverage of five territories in Europe and Northern Africa, which allowed to make comparisons among very different areas as far as concerning cultural aspects, food behaviors, and FW policy implementation level. Methodologically it should be pointed out the originality of the use of the model-based clustering approach for the identification of the FW profiles that combined with the weighted logistic model permitted the evaluation of the probability of belonging to the cluster of the household in the five territories providing a deeper analysis of the FW phenomenon.

Future research should expand the utilization of the questionnaire employed in the current study for FW measurements to encompass a broader range of geographic regions, territories, and countries, enabling a more comprehensive analysis of differences and similarities across locations. Furthermore, conducting a comparative analysis of territorial data with national data would provide valuable insights into the distinctive characteristics and nuances of specific regions in relation to nationwide statistics.

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CRediT authorship contribution statement

Benedetta Peronti: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Jacopo Niccolò Di Veroli:** Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Umberto Scognamiglio:** Data curation, Writing – review & editing. **Irene Baiamonte:** Writing – review & editing, Data curation. **Lilliana Stefanovic:** Writing – review & editing, Project administration. **Susanne Gjedsted Bügel:** Writing – review & editing, Funding acquisition, Data curation. **Lea Ellen Matthiessen:** Writing – review & editing, Data curation. **Youssef Aboussaleh:** Writing – review & editing, Funding acquisition. **Chaimae Belfakira:** Writing – review & editing, Data curation. **Dominika Średnicka-Tober:** Writing – review & editing, Funding acquisition, Data curation. **Rita Góralska-Walczak:** Writing – review & editing, Data curation. **Laura Rossi:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2024.142086.

Abbreviations

FLW	Food losses and waste
FW	Food Waste
TSS	Total Sum of Squares
RSS	Residual Sum of Square
ESS	Explained Sum of Squares
BIC	Bayesian Information Criterion
ICL	Integrated Complete-data Likelihood
EEV	Equal volume, Equal shape, Variable orientation

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