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Is that the way the cookie crumbles? Variation in household food waste by socio-demographics and food management behaviours

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ABSTRACT

Households produce more food waste than the rest of the supply chain combined in most countries. Identifying which households contribute most to food waste is important for designing and implementing effective interventions to reduce food waste. However, previous findings on the impact of socio-demographic characteristics and food management behaviours on household food waste are inconsistent and often rely on *self-reported* food waste data. In this study, we examined the association of socio-demographics and food management behaviours with directly measured food waste in 1783 UK households using waste compositional analysis. Our findings indicate that household size, age, and education significantly influence food waste levels, with individuals holding a university degree wasting less food, contrary to previous studies that analysed self-reported food waste levels. Additionally, the behaviours of purchasing the right amount of food, reusing leftovers, and defrosting items from the freezer are found to mediate the relationship between age and food waste. While purchasing the right amount of food and reusing leftovers are associated with lower food waste, households better at defrosting tend to waste more food, an intriguing and previously unreported finding. Our results suggest that future behavioural interventions should focus on these significant socio-demographic factors and food management behaviours to reduce household food waste.

1. Introduction

Household food waste is an environmentally, socially, and economically urgent problem that increases greenhouse gas production, food insecurity, and food price inflation (Stöckli et al., 2018). In industrialised and non-industrialised countries, households produce more food waste than the rest of the supply chain combined (Vittuari et al., 2023). In the UK, the country this study focuses on, household food waste makes up 60 % of all food waste, equating to 95 kg of food waste per person per year, with an estimated cost of £250 for the average person per year (WRAP, 2023).

Different types of behaviour-change interventions have been applied to reduce consumer food waste, such as national food waste prevention programs, local awareness campaigns, coaching, and prompts and tools for households (Swannell et al., 2023). For an intervention to be successful, its design and deployment will benefit from answers to the following questions related to households: (1) What types of foods are wasted, and what are the reasons for this waste? (2) Which households contribute most to food waste? (3) What behaviours are associated with this waste? Our study aims to answer questions 2 and 3 using existing waste composition analysis (WCA) data, which directly measures households' food waste by sorting food from non-food materials in relevant waste streams and weighing the amount of food present. However, our study does not address question 1 as it is the focus of another study.

Questions 2 and 3 have been investigated in previous literature largely through self-reported measures of food waste. To our knowledge, there are very few studies that have employed WCA, such as those by Hanssen et al. (2016) and Martianto et al. (2024). However, neither of these studies investigated the effects of food management behaviours on food waste levels.

Martianto et al. (2024) compared rural and urban households in Indonesia, focusing on the drivers of food waste (i.e., self-reported reasons for discarding food), the composition of waste, and the amount of food waste generated. They identified seven common drivers for discarding food, such as changes in texture, short shelf life, and forgotten items. However, the authors did not investigate how the drivers and composition of food waste affected the waste levels.

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Hanssen et al. (2016) examined the effects of age, household size, and type of residence on households' food waste in two municipality areas in Norway. Nevertheless, they did not find any significant differences across various sociodemographic categories.

Our study investigates how variations in food management behaviours and sociodemographic factors influence food waste levels, using WCA on a sample of 1783 households. This sample size substantially exceeds those of previous WCA studies, such as Hanssen et al. (2016) with 220 households and Martianto et al. (2024) with 215 households. While smaller WCA datasets are typically limited to detecting only large differences in food waste between different groups of households, our larger sample enables the identification of smaller differences with greater confidence. Additionally, our research provides novel insights into the relationship between food management behaviours and food waste, including their mediating role in the link between sociodemographic characteristics and measured food waste. Finally, our study provides new evidence from a different geographical and temporal context compared to most prior self-reported and WCA studies.

2. Literature review

Various methods have been developed and used to quantify household food waste. These include *self-reported* measures such as questionnaires and diaries, and *direct* measures such as WCA. The main disadvantage of self-reported measures is that their reliability depends on participants' characteristics, such as having a good memory (Edjabou et al., 2016) and biases like social desirability (Elimelech et al., 2018). Direct measures, including the WCA, are less susceptible to participant-related disadvantages (Giordano et al., 2018). However, they usually provide an incomplete picture of household food waste because they are applied to waste streams collected from households and do not account for food and drink that goes down the drain or is home-composted (Quested et al., 2020). Previous research showed that relying solely on self-reported data to estimate food waste may lead to underestimation. To address this, hybrid approaches, a combination of self-reported and direct measurement, have been suggested. Direct measurement is recommended if a hybrid approach is not possible (van der Werf et al., 2020).

2.1. Which socio-demographic characteristics of households correlate with levels of food waste?

The literature findings on the relationship between socio-demographics and household food waste are inconsistent and are mostly investigated through self-reported data. These inconsistencies may result from methodological differences between studies, but also reflect that socio-demographics correlate differently with food waste across different populations (e.g., in different countries). For example, higher or lower levels of food waste may not be directly driven by age but by variables that correlate with age, such as the time available for food-related activities and the experiences of different age groups (Wunder et al., 2019). Therefore, we report literature findings by highlighting the national context (e.g., the countries where research was conducted).

Van Geffen et al. (2017) suggested that age, gender, education level, household size and composition, employment status, and income are the most influential variables correlating significantly with self-reported food waste in four European countries (i.e., Hungary, Germany, Spain, and the Netherlands).

Regarding age, individuals over 65 in the Czech Republic and those over 55 in Australia were found to waste less food (Filipová et al., 2017; Karunasena et al., 2021). Through a case study with an over-65 group of individuals in the UK, Quested et al. (2013) found that older people were more likely to have a sense of frugality and engage more in food waste prevention behaviours, thereby generating less food waste.

Koivupuro et al. (2012) found that Finnish households where women are primarily in charge of grocery shopping generated more food waste. In the UK and Spain, however, men reported producing higher levels of food waste than women (Barr, 2007; Vidal-Mones et al., 2021).

Czech and Indonesian individuals with high incomes reported wasting more food (Filipová et al., 2017; Soma, 2019). However, Setti et al. (2016) indicated that the correlation between per capita income and food waste is not a simple linear regression but a 'U' shaped curve, suggesting that the value of food needs to be considered when examining the influence of income. After categorising food according to its value and studying the food waste of Italian consumers, the authors found that low-income households may waste more since they buy cheaper food with low quality or short shelf life.

Regarding the level of education, Fonseca (2014) found that highly educated Portuguese people reported wasting *less* food while Filipová et al. (2017) demonstrated that Czech consumers with A-level and university degrees wasted *more* than those with basic and secondary education. Secondi et al. (2015) found that individuals from 28 EU countries who finished their education aged 15 or under wasted less than those who finished it aged 20 or over. Some other studies conducted in Finland and the Netherlands and a cross-national survey study conducted in the UK, Spain, and Italy, however, showed that the impact of education on self-reported food waste is not significant (Koivupuro et al., 2012; Janssens et al., 2019; Bravi et al., 2020).

Grasso et al. (2019) demonstrated that those with full-time jobs in Denmark and Spain reported generating more food waste. Vidal-Mones et al. (2021) found that those employed but furloughed during the COVID-19 lockdown in Spain produced higher food waste, while those who were retired or unemployed generated less food waste.

The positive correlation between household size and food waste was reported in previous studies (Jörissen et al., 2015; Stancu et al., 2016; and Grainger et al., 2018). Nevertheless, Quested et al. (2013) and Williams et al. (2012) showed that per capita food waste decreases as household size increases.

Very few studies assessed the effect of socio-demographic characteristics on *directly measured* food waste. Quested and Luzecka (2014) found correlations between levels of food waste in the UK and age, number of people in the household, and employment status, with age and employment status being highly correlated with each other. In a study that was conducted with Norwegian households (Hanssen et al., 2016), participants aged 25–39 years generated the highest amount of edible food waste. Van Dooren et al. (2019) found that Dutch households with above-average incomes wasted almost twice as much food as those with below-average incomes. Martianto et al. (2024) concluded that households with higher income and education levels in urban areas of Indonesia tended to generate more food waste. A study by the Natural Resources Defence Council (NRDC) (2017) measured quantities and types of food waste at the city level across the USA and found significant but inconsistent results across the three cities regarding race and age.

2.2. What behaviours are correlated with household food waste?

Most studies investigating this relationship have focused on self-reported levels of food waste and food management behaviours (FMBs) (for a review, see Schanes et al., 2018). FMBs are proximal behaviours consisting of planning meals, shopping, storing, cooking food, and reusing leftovers (Quested et al., 2013). Van Geffen et al. (2017) found that lower impulse buying, checking the food in stock, cooking precisely, and using leftovers across Hungarian, German, Spanish, and Dutch samples were correlated with lower levels of self-reported food waste. Bretter et al. (2022) and Stancu et al. (2016) conducted research in the UK and Denmark, respectively. Their results showed that leftover reusing and planning behaviours were directly associated with less food waste. We also note that the relationship between FMBs and food waste is likely complex, depending as much on the interaction between multiple behaviours and their context (Boulet et al., 2021) as it does on single behaviours (Hebrok and Boks, 2017).

Unless a study is observational, recording participants' actual behaviours, FMBs are examined, asking participants about the frequency of their FMBs or their self-judgments (i.e., how good or bad they are in engaging behaviours). In both cases, the responses may not be the same as their actual FMB's. The survey items we analysed in our study asked participants about their self-judgments of their FMBs.

Fewer studies have examined the impact of FMBs on directly measured food waste. A US study by the NRDC (2017) concluded that purchasing, preserving, cooking, and eating food can significantly impact whether food is ultimately consumed or thrown away. Quested and Luzecka (2014) found at least moderate evidence of correlations between levels of food waste in UK households and using leftovers, meal planning, list making, use of the fridge to store apples, cooking the right amount of rice and pasta, and buying less of other items when purchasing special offers. Van Dooren et al. (2019) demonstrated that making shopping lists and planning meals ahead (compared to deciding what to eat on a daily basis) reduced Dutch households' food waste, whereas not buying the right amount of food increased food waste.

2.3. Aim and research questions

Understanding which households waste more or less food is useful for supporting the design and implementation of interventions (in the broadest sense of the word) aiming to reduce the amount of food wasted in households. With new data available from waste compositional analysis for the UK and gaps in our prior understanding of these correlations, we aimed to assess the effects of socio-demographic factors (i.e., age, gender, income, education, working status, household size, and living situation) and managing food (i.e., planning, shopping, storing, cooking, and reusing leftovers) on this directly measured food waste. Our research questions are,

1. Which socio-demographic variables are associated with food waste in UK households?
2. Which food management behaviours predict higher or lower food waste in UK households (when controlling for other behaviours)?

3. Methods

3.1. Data source

This research uses data from an in-kind contribution to the study by WRAP, a climate action NGO. Two sets of data were analysed: (1) a waste compositional analysis (WCA) dataset, detailing the types and quantities of food waste generated by households, and (2) a questionnaire completed by the same households that assessed residents' attitudes, knowledge, and behaviour in household food management, in addition to their socio-demographic information. Food management was assessed with the question, "How good or not would you say you/your household is at each of the following?" The socio-demographic and behaviour questions are listed in the Supplementary information (see S1).

The fieldwork was undertaken in England and Wales; however, the sample was selected to be representative of the whole UK ($N = 1801$). Local authorities and households were selected for inclusion in the study based on two key factors: The residual collection frequency and food waste collection service offered, as well as demographic factors, specifically the deprivation level and population density of the local authority (see WRAP, 2023 for additional information).

Each local authority selected households according to demographic classification using the UK Office for National Statistics' demographic classification system.

A face-to-face doorstep survey approach was adopted to ensure a high response rate and residents' consent to the waste composition analysis. Only those who were either solely or mainly responsible for food shopping or food preparation were included in the study. The survey was undertaken in two waves: Between 25 October and 17 December 2021 and between 4 January and 27 February 2022.

Due to the broad scope of the study, which covered multiple constructs alongside socio-demographic characteristics, the survey included single-item measures to assess behaviours.

Waste compositional analysis (WCA) was undertaken between November 2021 and March 2022. Food waste was sorted and weighed for each household according to detailed food categories (e.g., peel of a potato, wholemeal standard bread, or used teabags/loose tea). Food waste can subsequently be attributed to (anonymised) individual households and linked to the household survey data, which details each household's demographic and food management information. In an earlier analysis of the dataset, each item was classified as "edible parts" (i.e., wasted food), "inedible parts" (e.g., eggshells), or partly edible (i.e., containing edible and inedible parts), and assigned an edibility percentage accordingly (WRAP, 2023). This process obtained the total weight of edible parts of food waste produced by each household in residual collections, separate food waste collections, and mixed garden and food waste collections. Edible food waste was used instead of total food waste because the edible portion of food could have been consumed and, therefore, avoided. Waste collections occurred every one or two weeks, depending on the collection frequency. For households with a two-week collection period, the amount of waste was converted to a "per week" figure. All waste from households was collected during this period. Surveys were linked using a unique household identifier.

Due to the expense, time, and logistical complexity of WCA data collection, it was not feasible to sample households throughout the entire year or to increase the sample size beyond the selected households. As a result, each household's data represents a brief period, typically ranging from one to two weeks.

A hybrid approach was used for UK reporting of household food waste, where drink waste was estimated using food diaries. However, the households participating in the diary study were not the same as those included in the WCA. Consequently, it was not possible to create a combined dataset encompassing all disposal routes, as households were only included in either the WCA or the diary study, but not both. Importantly, the food diary data were not used in our analysis; only data from the WCA and the accompanying household questionnaire were analysed.

3.2. Procedure

We assessed the relationship between the weight of food waste classified as "edible parts" for each household and their socio-demographics and food management behaviours (Fig. 1). IBM SPSS 26 and R Studio were used for data analysis.

Outliers were determined and removed from the dataset using the interquartile range (*IQR*) method. Thus, households with a level of edible food waste above the upper fence ($Q3 + 1.5xIQR$) and below the lower fence ($Q1\text{-}1.5xIQR$) were identified. Removing the outliers ($N = 18$) resulted in a sample size of 1783. Next, descriptive statistics were used to illustrate the distribution of households' socio-demographics and food management behaviours.

A Kolmogorov-Smirnov (K-S) test ($D(1783) = 0.138$, $p = .000$) did not suggest a normal distribution. Therefore, we applied generalized linear modeling (GLM) with a gamma distribution and log-link function (as employed by Quested and Luzecka, 2014) in a multivariate model because GLM has no restrictions on the distribution of variables.

In each GLM model conducted, household size and home composting were included as control variables. These two variables showed a significant association with food waste in previous studies (Quested and Luzecka, 2014; Schanes et al., 2018), and Pearson Chi-Square test results showed that household size and home composting significantly correlated with most socio-demographic factors. Household size significantly correlated with all socio-demographics except for gender. Home composting was not significantly correlated to working status or gender but

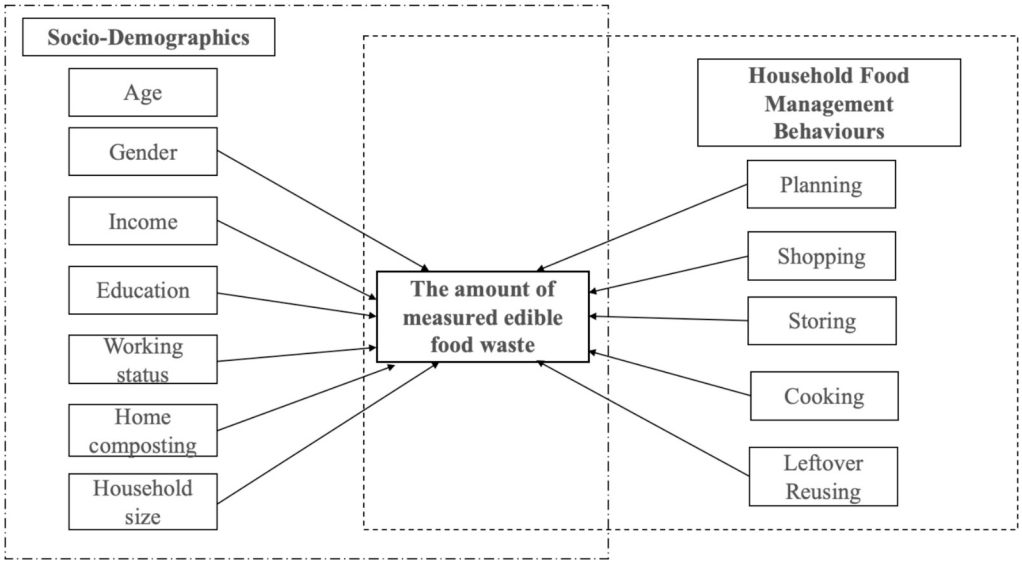

Fig. 1. The research framework.

significantly correlated to all other socio-demographics. Thus, not controlling for home composting or household size could lead to false positives in model outputs.

We first entered all socio-demographic factors into the multivariate model and removed them stepwise, starting with the least significant variables until only the variables at the 5 % significance level remained. Next, we conducted pairwise comparison tests to investigate the significant results further. We also applied the same approach to assess the relationship between behaviours and wasted food.

4. Results

4.1. Descriptive statistics

Descriptive statistics for the socio-demographics of households are provided in Table 1. The results demonstrate that almost half of the survey respondents were in the age group of 35–64 (47 %), about two-thirds were females (63 %), and the majority were educated up to a university level (61 %). More respondents reported themselves as "only stay-home people" (41 %) than "only employed" (37 %) and "employed people with stay-home people" (22 %). Nearly half of the households consisted of two occupants (44 %), and 15 % of the households were home-composting their food waste. A comparison of the sample composition with the most recent data from the UK Office for National Statistics (ONS) indicates that our sample consisted of more females (63 % vs. 51 %), more people over 65 (39 % vs. 19 %), and fewer low-income people (20 % vs. 42 %) than the ONS data.

Table 2 shows descriptive statistics regarding participants' food management behaviours. The results suggest that *Checking the fridge temperature* (M = 2.48, SD = 1.50) and *Batch cooking* (M = 2.59, SD = 1.55) were the items with the lowest ratings, whereas the most highly rated items were *Buying the right amount of food* (M = 3.97, SD = 0.73), *Managing/keeping track of food in the fridge for your household's needs* (M = 3.94, SD = 0.79) and *Defrosting items from the freezer* (M = 3.94, SD = 0.88).

4.2. The effects of socio-demographic factors on measured household food waste

The results of a pairwise comparison test using the Least Significant Difference (LSD) suggest that household size, home composting, age, and education have significant effects on the weight of edible food waste. Fig. 2 presents estimated marginal means (EMMs) of the amount of food waste per household per week regarding these significant variables.

Households of one or two people produce significantly less food waste than those that live in a household of three or more people. There is also a significant difference between the amount of food wasted by a household of one person compared to two people (MD = -187.907, SE = 86.362, p = .030). However, there is no significant difference in the amount of waste produced by households of three, four, and five people.

Table 1
Socio-demographic characteristics of households: Age, gender, income, education, working status, household size, and home composting.

Socio-demographics	N	%[a]
Age		
18–34	252	14 %
35–64	841	47 %
65+	690	39 %
Gender		
Female	1130	63 %
Male	651	37 %
Prefer not to say	2	0.1 %
Income		
Low income (lower than £19,999)	361	20 %
Middle income (£20,000–£49,999)	548	31 %
High income (higher than £49,999)	308	17 %
Prefer not to say	566	32 %
Educational level achieved		
Up to university	1087	61 %
University degree	559	32 %
Higher university degree	95	5 %
Others (e.g., still in full-time education)	42	2 %
Working status		
Only employed people	653	37 %
Only 'stay-home' people	741	42 %
Employed people with 'stay-home' people	389	22 %
Household size (number of occupants)		
1	363	20 %
2	778	44 %
3	291	16 %
4	231	13 %
5+	119	7 %
Prefer not to say	1	0 %
Home composting		
Composted	265	15 %
Did not compost	1496	84 %
Other (do not specify)	22	1 %

[a] Note: Rounded values may add up more or less than 100 %.

Table 2
Descriptive statistics for the food management items (measured on a 1–5 scale, where 1 = I don't generally do this, 2 = poor, 3 = satisfactory, 4 = good, 5 = excellent) and for the weight of edible food waste (measured in grams).

Food management category	Item	N	Range	Mean (±SD)
Planning	Making a meal plan for the week ahead	1783	1–5	3.12 (±1.39)
	Making a detailed shopping list	1782	1–5	3.51 (±1.29)
Shopping	Buying the right amount of food for your household's needs	1783	1–5	3.97 (±0.73)
Storing	Managing/keeping track of food in the fridge	1783	1–5	3.94 (±0.78)
	Checking/changing the fridge temperature regularly	1783	1–5	2.48 (±1.50)
	Freezing raw meat, bread, and leftovers	1783	1–5	3.48 (±1.31)
	Defrosting items from the freezer	1779	1–5	3.94 (±0.87)
Cooking	Making a meal by combining foods/random ingredients	1783	1–5	3.79 (±0.99)
	Portion sizing – accurately judging how much to prepare	1783	1–5	3.89 (±0.88)
	Batch cooking (e.g., making several portions to store)	1782	1–5	2.59 (±1.54)
Leftover reusing	Using up leftovers	1783	1–5	3.79 (±1.06)
–	Weight of edible food waste (grams)	1783	1.00–9075.48	1855.32 (±1742.51)

Households that compost at home produce significantly less wasted food (around 0.5 kg or less) in their kerbside containers than those that do not (MD = -552.942, SE = 110.753, $p < .001$). These results suggest that it is important to include both household size and home composting as controls in the model, given the strength of the relationship between these variables and the amount of food waste.

The results also show that respondents aged between 18 and 34 and those between 35 and 64 wasted more than those over 65 (MD = 333.626, SE = 142.419, p = .019 and MD = 402.976, SE = 99.25, $p < .001$, respectively). Regarding education, people with a high school degree or less wasted more food than those with undergraduate university degrees (MD = 215.49; SE = 99.87, p = .031) and higher university degrees (MD = 433.51, SE = 172.488, p = .012). The effect size for the socio-demographic model, as measured by McFadden's R^2, was 0.029. The low effect size is not uncommon in cross-sectional consumer datasets, where a substantial portion of the variance may be attributed to unobserved or unmeasured factors, which is discussed in Section 5.3 on limitations. The effects of gender, income, and working status were insignificant and were therefore removed from the model to create the pared-down model. The results of the multivariate analysis are provided as Supplementary information (see Table S1).

4.3. The effects of food management behaviours on measured household food waste

Table 3 demonstrates that buying the right amount of food, defrosting items from the freezer, and reusing leftovers significantly correlate with the amount of wasted food by a household. The results for home composting and household size are presented as Supplementary information (see Table S2).

Specifically, buying the right amount of food is negatively correlated with waste levels: participants who were excellent in buying the right amount of food (score = 5) wasted, on average, 28.2 % less than those who generally did not buy the right amount of food (score = 1). Regarding leftover reuse, an 8.1 % increase in waste level with each unit of the behavioural score is observed, indicating that households that were excellent in reusing leftovers wasted 36.6 % less than those that did not generally reuse leftovers. Regarding defrosting items from the freezer, there was a 7.95 % decrease in waste level with each unit of the behavioural score. This suggests that households that were excellent at defrosting food wasted 28.2 % more than those that generally did not defrost food. The effect size of the model, as measured by McFadden's R^2, was 0.019, indicating a small effect size. This limitation is discussed further in Section 5.3. However, given the statistically significant relationships—likely detectable due to the large sample size—the model still offers robust insights into the relative importance and direction of behavioural predictors of food waste levels.

The eight food management behaviours that did not significantly associate with food waste and excluded from the model include; Making a meal plan for the week ahead (B = −0.027, SE = 0.020, p = .188); Managing/keeping track of food in the fridge (B = 0.045, SE = 0.041, p = .270); Freezing raw meat, bread and leftovers (B = −0.021, SE = 0.023, p = .367); Making a meal by combining foods/random ingredients you happen to have (B = 0.026, SE = 0.030, p = .399); among others. See Table S3 in the Supplementary information for all insignificant items excluded from the final behavioural model.

4.4. Food management behaviours as mediators of age and education effects on food waste

To investigate how age and education influence household food waste through behavioural pathways, we examined the role of food management behaviours as potential mediators. We first conducted ANOVAs to identify significant differences in food-related practices across age and education groups. This was followed by mediation analyses to assess whether these behavioural differences could statistically account for the observed variations in food waste. The results below outline our findings.

We conducted a series of ANOVAs, followed by post hoc comparisons, to explore age-related differences in food management behaviours that may influence food waste levels. The results indicate that older adults (i.e., 65+) engaged significantly more than the 18–34- and 35–64-year groups in *buying the right amount of food* ($p < .001$), *managing/keeping track of food in the fridge* ($p < .001$), and *portion sizing* (i.e., accurately judging how much food they need to prepare) ($p < .001$). Additionally, those aged 65+ outperformed the 18–34 group in *making a detailed shopping list* (p = .009), *checking or changing the fridge temperature on a regular basis* (p = .004), *freezing meat, bread, and leftovers* (p = .010), *defrosting* (p = .017), and *reusing leftovers* (p = .027). While these findings highlight significant behavioural differences between younger

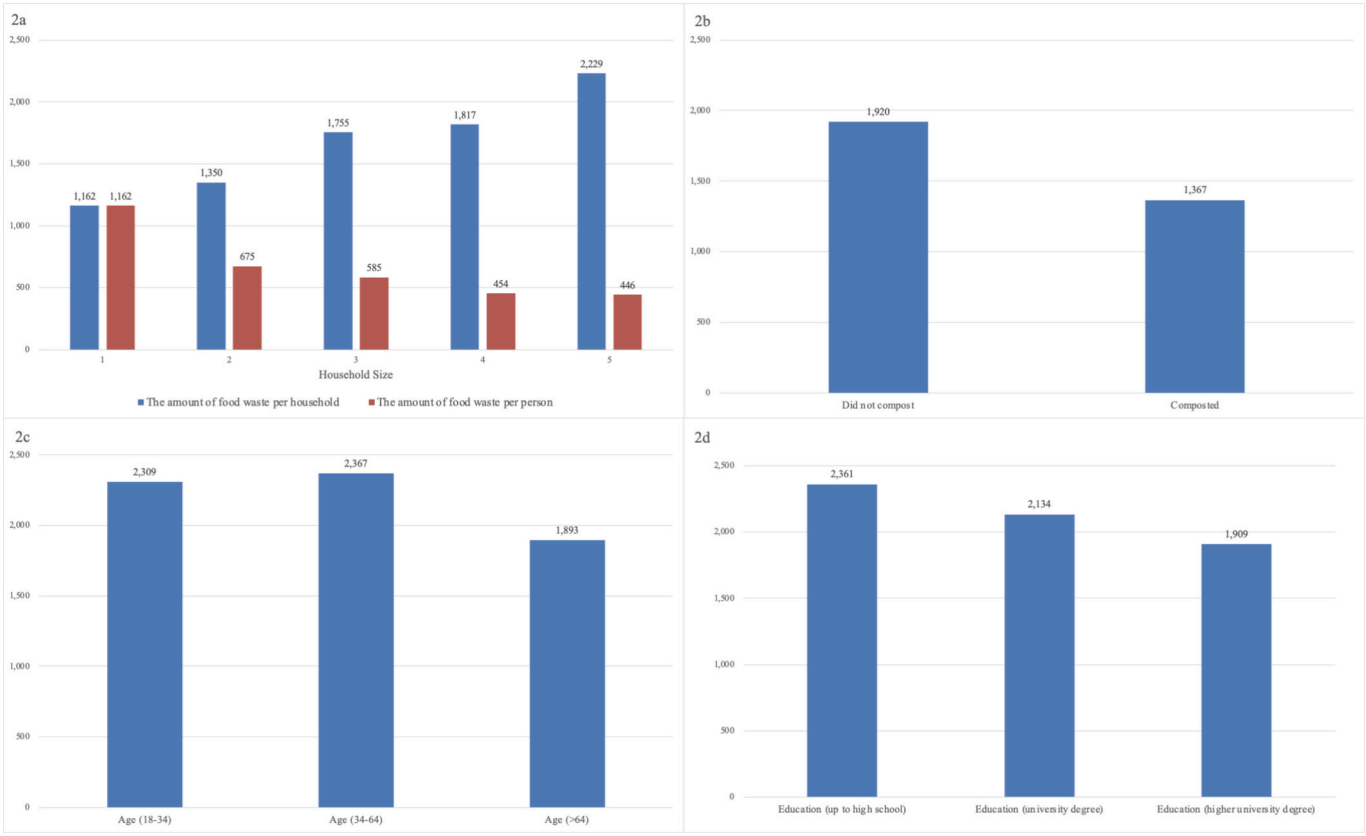

Fig. 2. (a) The amount of food waste per household vs. per person by household size (estimated marginal means). (b) The estimated marginal means (EMMs) of the amount of food waste (grams/household/week) regarding (no)home composting. (c) The EMMs of the amount of food waste (grams/household/week) regarding age groups. (d) The EMMs of the amount of food waste (grams/household/week) regarding educational level.

Table 3
Effects of food management behaviours on the weight of edible food waste (g), with a "pared-down" model and household size and home composting controlled.

Categories	Items	*B	Standard error	Wald χ^2	p-Value
Shopping	Buying the right amount of food for your household's needs	−0.062	0.038	2.723	0.047
Storing	Defrosting items from the freezer	−0.083	0.033	6.274	0.013
Leftover reusing	Using up leftovers	−0.078	0.026	8.658	0.003

*B represents unstandardized regression coefficients. McFadden's $R^2 = 0.019$. ** $p < .05$, ***$p < .001$.

individuals and those aged 65 and over, they may not fully capture the complexity of the relationship between age and food waste.

Next, we conducted a mediation analysis to further investigate whether specific food management behaviours mediate the relationship between age and food waste. Our analysis revealed that three behaviours significantly mediated this relationship. Specifically, *buying the right amount of food* (indirect effect = −16.78, 95 % CI [−35.66, −1.92]) and reusing leftovers (indirect effect = −11.32, 95 % CI [−25.22, −1.82]) were associated with lower levels of food waste among older individuals. In contrast, *defrosting* (indirect effect = 8.51, 95 % CI [0.32, 20.11]) was associated with a slight increase in food waste, suggesting that this behaviour may not be effective in reducing waste.

We followed a similar procedure to that used in the age analysis to gain a better understanding of educational differences in food management behaviours that may influence food waste levels. The post hoc comparisons following a series of ANOVAs indicated that people with a university or higher degree reported significantly greater engagement than those with no university degree in making a meal plan for the week ahead ($p = .017$ and $p = .013$, respectively) and batch cooking ($p = .004$ and $p < .001$). However, the subsequent mediation analysis did not identify these or other food management behaviours as significant mediators of the relationship between educational level and food waste.

5. Discussion

We examined the effects of socio-demographic factors (i.e., age, gender, income, education, working status, household size, and living situation) and food management behaviours (with specific actions grouped into the following categories: planning, shopping, storing, cooking, and reusing leftovers) on measured food waste using waste composition analysis (WCA) data. Previous studies often utilised diaries and self-reported measures. However, these methods are prone to underestimating household food waste, leading to erroneous results. Correlations with self-reported measures of food waste could be due to real differences in levels of food waste or to differences in under-reporting between different groups of the population. Still, very few studies assessed the effect of sociodemographic and behavioural factors on the amount of food waste produced by a household using WCA (Quested and Luzecka, 2014; NRDC, 2017; Van Dooren et al., 2019).

5.1. Socio-demographics and household food waste

Our results showed that age is a significant factor in understanding the amount of edible food waste in households. Participants older than

65 wasted less than the younger age groups. This result is in line with previous research based on self-reported food waste (e.g., Hermanussen et al., 2022; Thyberg and Tonjes, 2016; Van Geffen et al., 2017) and research that utilised WCA data (Quested et al., 2013; Quested and Luzecka, 2014). A literature review by Vittuari et al. (2023) attributed the findings about people over 65 to personal experiences of older generations with food scarcity during and after World War II, which resulted in higher levels of awareness about the impacts of food waste compared to younger participants. However, research by Quested and Luzecka (2014) showed that older people do not cite food waste as a concern any more than younger generations. In line with this finding, Karunasena et al. (2021) attributed older people's lower food waste to their lower proportion of impulse buying and resistance to promotional offers (e.g., buy one get one free) compared to those aged 18–34. Younger generations, however, are likely to lead different lifestyles. For example, they are more likely to cite 'time pressures,' 'not knowing how to reduce food waste,' and 'having more important things than food waste to worry about' than older generations (Ghinea and Ghiuta, 2019; Makowska et al., 2024).

Our findings highlight the significant impact of age on food management behaviours. Older adults (i.e., those aged 65 and above) consistently reported better engagement in various food management behaviours, including *buying the right amount of food*, *portion sizing*, *defrosting*, and *reusing leftovers*. This aligns with previous research indicating that older individuals may be more mindful of food usage due to life experiences, such as having lived through periods of scarcity, or because they have established routines and habits regarding food.

We also identified three behaviours that help to explain age-related differences in wasting food. Specifically, *buying the right amount of food* and *reusing leftovers* were associated with lower levels of food waste among older individuals. In contrast, *defrosting* was associated with a slight increase in food waste, suggesting that this behaviour may not be effective in reducing waste. These behaviours partially mediated the relationship between age and food waste, as the direct effects of age remained significant even after accounting for them. This indicates that while food management behaviours contribute to age-related differences in food waste, other factors, such as lifestyle, values, or broader socio-cultural influences, may also play a role. For example, younger individuals may face more time constraints, less stable routines, or different priorities, which could affect their ability to manage food effectively, even if they are aware of best practices.

Educational attainment is also correlated with levels of household food waste. Our results suggest that participants with a university degree or higher wasted less food than those without a university degree. This result contrasts with previous studies that found significant correlations between higher levels of education and higher levels of food waste (e.g., Fonseca, 2014; Secondi et al., 2015; Filipová et al., 2017). The difference in findings may have resulted from different methods of collecting food waste data (i.e., WCA vs self-report). Our data results from a WCA, a direct measure of household food waste, so it does not rely on participants recalling how much food they have wasted. Therefore, it is a more reliable indicator of how much food is wasted in a household. Differences with other research may also result from the varying locations of studies, as researchers' categorisations of educational levels can differ by country. Additionally, the length of time in education may not be the main driver behind the correlation; other factors, not measured in the survey and correlated to education levels, may have led to different levels of food waste.

Our findings indicate that participants with a university degree or higher reported better engagement in behaviours such as meal planning and batch cooking, which may reflect higher food literacy, better access to resources, or lifestyle routines that support proactive food management. However, while these behaviours were more common among highly educated individuals, they did not explain the differences in food waste levels. This suggests that education may be linked to other underlying factors, such as environmental attitudes, income stability, or time availability, that influence food waste in more complex ways. These findings highlight the need for future research to examine how educational background interacts with broader social and behavioural contexts to shape food-related decisions and outcomes.

Our results also showed how the number of people in a household is associated with the total amount of food wasted per household. The differences between smaller households are more pronounced, with households with one and two people being significantly different from one another, yet households with three, four, and five or more people all have similar amounts of household food waste. This finding is similar to previous UK household food waste research (Quested and Luzecka, 2014).

We did not find significant effects of gender or income on levels of food waste. In their review article, Pilone et al. (2023) highlighted inconsistent literature findings regarding the effect of gender and income on food waste. The authors concluded that this may result from collecting self-reported food waste data through surveys. However, by employing WCA, a reliable food waste measurement methodology, we showed no significant effect of gender and income on wasted food. This result may suggest that gender and income are not key determinants of the amount of food waste in UK households. Alternatively, previous inconsistent findings may stem from potentially different relationships among factors in different countries and geographies.

We did not find any significant association between working status and the amount of food wasted by households, contrasting the findings of Quested and Luzecka (2014). By utilising WCA data, the authors found that households with a retired person as the main earner produced significantly less food waste and partly explained their result by the fact that retired people were older. By classifying retired participants as stay-at-home, however, we may not have found a significant relationship between working status and the amount of food waste.

5.2. Food waste management behaviours and household food waste

Our results indicate that buying the right amount of food and reusing leftovers are significantly associated with lower levels of food waste. Recent reviews investigating the drivers of household food waste have also shown that buying the right amount of food and reusing leftovers correlated with lower levels of food waste (Dos Santos et al., 2022; Van Geffen et al., 2020). These correlations, however, are not necessarily causal: the generation of food waste is the result of many activities, decisions, and contextual factors that could be investigated further. Nevertheless, our results indicate where the greatest opportunities to reduce food waste in UK households might be: Interventions, for example, communicating to the public, providing training and education, and changing the grocery retail environment to help people buy the right amount and reuse leftovers. In particular, supermarkets have a key role in helping households buy the right amount of food. They can ensure the availability of appropriate pack sizes for all households alongside pricing and promotional structures to prevent consumers from buying more than their households require. For many vegetables and fruits, selling loose, rather than in packaging, could also enable consumers to buy an appropriate amount for their households' needs (WRAP, 2024).

Our research also shows that households that are better at defrosting items from the freezer tend to waste more food. To our knowledge, behaviours about freezer management have not been previously found to increase wasted food. Although there is a need for further research to assess the relationship between freezer management and food waste, we hypothesise that if food placed in the freezer is poorly managed, it may end up being wasted. Karunasena et al. (2021) found that households that forget about stored food most of the time (in the fridge and freezer) are 20 % more likely to discard food compared to those who rarely or never forget. It was also found that 50 % of UK households reported being poor at keeping track of food in their freezer (WRAP, 2019).

These findings align with previous research that emphasises the

difficulties of managing frozen food at home. Janssen et al. (2017) found that food waste from freezers often occurs due to infrequent and inadequate checking of stored items. This oversight can lead to products being overlooked during meal planning and grocery shopping. The authors also noted that certain categories, such as frozen ready-made meals, tend to be disposed of more frequently than their fresh or ambient counterparts. This suggests that the freezer, while designed for preservation, can also serve as a "waiting room" for surplus or uncertain-use items, as noted by Evans (2012). When not integrated into regular household routines, these items may risk being forgotten and ultimately discarded.

Alternatively, this significant relationship may not be directly related to freezer management but to other factors that explain the increased levels of food waste. To investigate this, we examined the correlations between engagement with defrosting and the variables: freezer capacity, understanding of date labels, and working status (as it may reflect a busy or relaxed lifestyle). Our findings indicate that while working status did not have a significant correlation with defrosting behaviour, there were weak yet significant correlations with freezer size ($B = -0.077$, $p = .001$) and understanding of date labels, specifically the use-by and best-before dates ($B = 0.094$, $p < .001$ and $B = 0.129$, $p < .001$, respectively). These results highlight the importance of further research for investigating the relationships between many survey variables and defrosting behaviour to identify any potential confounding variables. Trialling different interventions/approaches aiming at reducing household food waste and evaluating them would significantly enhance our understanding of the most effective methods in various situations.

We did not find any significant relationships between the levels of food waste and cooking and meal planning behaviours. However, Van Geffen et al. (2017) showed that an overview of the food in stock and cooking precisely were associated with lower food waste. Bretter et al. (2022) showed a negative correlation between planning meals ahead and food waste. In an integrative review on why people waste food at home and how it can be prevented, Van Geffen et al. (2020) highlighted that meal planning reduces food waste because planning increases purchasing accuracy. However, the authors also noted that too much planning could lead to waste. Therefore, the differences in literature findings may result from methodological and geographical differences. Particularly, unlike our study on measured food waste, the studies mentioned above employed self-reported food waste data. We recommend intervention studies, including evaluated trials and pilots of solutions capable of being deployed across wide sections of the population. These studies should focus on a range of behaviours to understand which to focus on to achieve sustained reductions in the amount of wasted food.

5.3. Limitations

We focus on key limitations, including the data collection methodology and how insights should be interpreted.

First, while our research utilised WCA data that avoids under-reporting biases associated with self-reported levels of food waste (van der Werf et al., 2020; Quested et al., 2020), the data represent only a short time frame window for each household Because households can waste different amounts each week, this variability introduced unexplained variance that limited the explanatory power of our models. This is reflected in the low effect sizes of the sociodemographic and behavioural models (Sections 4.2 and 4.3). Despite these limitations, the sample was large enough to provide robust insights.

Second, our research utilised a survey to assess households' socio-demographics and behaviours, relying on the responses of participants. This is particularly relevant to questions on behaviours, as different households may perceive how well they do a behaviour differently from one another. This is a limitation in most survey studies and can only be circumvented by observing a household over a long period. However, observational studies have drawbacks, such as being time-consuming, expensive, and potentially altering the behaviours of those being observed. Additionally, we acknowledge that single-item measures may not fully capture the complexity of the constructs being studied, potentially limiting the depth and nuance of the findings. Therefore, we suggest that future research incorporate multi-item validated scales to enhance the reliability, validity, and generalizability of the findings.

Third, our sample differs from national averages in some key respects. Compared to the most recent UK Office for National Statistics (ONS) data, our sample included a higher proportion of females (63 % vs. 51 %), individuals over 65 (39 % vs. 19 %), and fewer low-income participants (20 % vs. 42 %). These demographic differences may limit the generalizability of our findings to the broader UK population. For example, older individuals and those with higher incomes may engage in different food management behaviours or face different constraints than younger or lower-income groups. Future research should aim to replicate these findings in more demographically representative samples to strengthen external validity.

Fourth, our research does not provide insights into causal relationships. Thus, it does not prove that performing a particular behaviour leads to less waste. The effects may result from other actions of households. For example, to buy the right amount of food, the household may perform several planning activities for their meals, thereby contributing to lower food waste levels.

6. Conclusions

Our study shows that age, household size, and education are the socio-demographic factors that explain the amount of directly measured food waste. Those with a university degree waste less than those without a degree, contrary to previous self-report studies that found significant correlations between higher levels of education and higher levels of food waste. Further research is needed to investigate what other factors contribute to explaining wasted food and are associated with these key socio-demographic groups, therefore enabling the practitioners (e.g., local authorities, environmental NGOs and organisations) to design behavioural interventions for a given demographic group.

Buying the right amount of food and reusing leftovers are significantly correlated with lower levels of wasted food, suggesting that practitioner organisations should target these behaviours in their interventions at households to reduce food waste levels. Our results also show that households that are better at defrosting items from the freezer tend to waste more food. To our knowledge, behaviours relating to the use of the freezer have not previously been found to be positively correlated with wasted food. Therefore, future research should examine the underlying reasons for this novel association. A promising direction for future research is to investigate whether this relationship is moderated or mediated by variables such as household routines (e.g., frequency of bulk shopping, meal planning practices, or reliance on frozen convenience foods), psychological traits (e.g., impulsivity, time management, or planning efficacy), and cultural norms related to food storage and consumption. These factors may systematically interact with freezer-related behaviours, potentially contributing to increased food waste. Given the complexity of food waste behaviours shaped by multiple, interacting decisions and contextual influences, clarifying these mechanisms could inform the design of targeted and context-sensitive intervention strategies. Such insights would enhance the practical relevance and effectiveness of efforts aimed at reducing household food waste.

Our findings can help future research in the following ways: Investigating behavioural and lifestyle factors associated with people over 65 or people buying the right amount of food may help explain why food waste is lower in these groups. Other factors associated with households being better at defrosting food from the freezer would help explain why this behaviour results in more wasted food. To investigate these research questions, secondary analysis and direct observations can be applied.

Secondary analysis could explore a larger range of factors than we were able to do in this study. Similar Generalized Linear Models could be used to explore factors and topics, including time available to households, use of date labels, and eating habits.

Other alternative statistical methods can be used to delve deeper into the data used in this research. For example, cluster analysis can be used to create groups of similar households associated with different amounts of household food waste. This may help build a household profile that can be targeted in behaviour change campaigns.

CRediT authorship contribution statement

Gülbanu Kaptan: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Investigation, Conceptualization. **Tom Quested:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Conceptualization. **Chuyao Kuang:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Marcel Torode:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Data curation.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly to correct the grammatical errors in the manuscript. After using Grammarly, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Gulbanu Kaptan was a member of the European Commission's European Food Waste Forum between 2021 and 2023. This was a paid appointment for her advisory role.

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Appendix A. Supplementary data

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