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# Towards Sustainable Food Systems: Exploring Household Food Waste by Photographic Diary in Relation to Unprocessed, Processed and Ultra-Processed Food

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**Abstract:** Global society is wasting food at unsustainable levels, and unconsumed food is contributing markedly to carbon emissions. Simultaneously, food insecurity and obesity are increasingly prevalent concerns in high-income countries. This study aimed to evaluate food waste at the household level to understand relationships between discarded food, food processing and household characteristics. A sociodemographic and food security survey of householders in Hampshire (UK) was conducted alongside a seven-day photographic food waste diary. Of the total food waste from 94 participants, 87% was unprocessed, 51% was avoidable or potentially avoidable and 36% was unavoidable. Of the total food waste, 61% occurred during food preparation. Greater amounts of avoidable food waste occurred in one, three and four+ person households than in two-person households. Potentially avoidable food waste was greater in households educated to postgraduate and university degree level than others. The outcomes of this study indicate that the focus on interventions should vary demographically. Interventions that support food security, improving diet quality and saving money, while reducing avoidable and unprocessed food waste, in one, three and four+ person households during food preparation are one option. Reducing potentially avoidable unprocessed food waste is a priority in households educated to university degree level and above.

**Keywords:** food waste; food security; processed food; ultra-processed food; diet quality; nutrition; household; consumer; photographic diary



**Citation:** Barker, H.; Shaw, P.J.; Richards, B.; Clegg, Z.; Smith, D.M. Towards Sustainable Food Systems: Exploring Household Food Waste by Photographic Diary in Relation to Unprocessed, Processed and Ultra-Processed Food. *Sustainability* **2023**, *15*, 2051. https://doi.org/10.3390/su15032051

Academic Editors: Taghi Miri and Helen Onyeaka

Received: 16 December 2022
Revised: 18 January 2023
Accepted: 18 January 2023
Published: 21 January 2023



## 1. Introduction

Global society is producing an unsustainable 931 million tonnes of food waste each year, and 8–10% of global carbon emissions are linked to unconsumed produce [1]. Although food is wasted or lost throughout the food supply chain, the greatest percentage of food waste/loss in high-income countries occurs during the consumer stage, especially at the household level [2,3]. Household food insecurity, where people cannot feed themselves without external support, is a serious public health concern even in high-income countries [4,5]. In the UK, for example, at least 6% of the population are food insecure, while households waste on average the equivalent of eight meals per week [6,7]. With the backdrop of Brexit, the COVID-19 pandemic, the Russia–Ukraine war and rising costs of living [8], even households with a previously sufficient income may experience difficulties in affording food in comparison to previous years. The United Nations Sustainable Development Goals (SDG) highlight both food insecurity and food waste as key concerns (SDG 2 Zero Hunger and Goal 12.3 Responsible Consumption and Production) [9]. Measures to mitigate food insecurity include welfare entitlements and food aid, such as food banks and other charitable food services whereby food deemed 'surplus' is redistributed to those in need. Such measures may do little to address the underlying causes of food insecurity, which are largely economic [5], and it has been proposed that 'solutions likely lie upstream

in social protection policies' [4]. It is known that societal, personal, product and behavioural factors influence food waste [10–12]; thus, for social context, aspects such as household size, educational attainment and household income should be considered in relation to food waste.

Additionally, the prevalence of obesity is increasing in every region of the world and is associated with poorer diet quality [13]. In the UK, the most recent National Diet and Nutrition Survey (NDNS) report confirms that overall the population does not consume the recommended levels of fruit and vegetables or fibre and consumes more sugar and saturated fat than is recommended [14]. The purchasing and consumption of ultra-processed food (typically with a longer shelf life) are associated with obesity [15], higher food intake, higher fasting glucose, metabolic syndrome, the risk of hypertension and increases in cholesterol [16]. There is, however, a paucity of research that explores the links between diet quality and food waste [17]; both issues are distinct but implicitly connect to behaviour concerning food choices. We propose that supporting households to reduce avoidable food waste from unprocessed food could address food security by improving dietary health. Reducing unprocessed food waste could result in nutrients that are falling below recommended levels becoming available for consumption and would therefore improve the nutritional status of the population [14]. In this regard, the NOVA Food Classification System (Table 1) is instructive, emphasising that "natural or minimally processed foods and freshly made dishes and meals" have higher health benefits than ultra-processed foods (p.35) [18].

**Table 1.** Definition of the NOVA Food Classification System [18].

| NOVA Category | Definition | Examples |
| --- | --- | --- |
| NOVA 1 | Unprocessed or minimally processed foods. Undergoing no alteration following removal from nature. Minimally processed foods may involve cleaning, removal of unwanted or inedible parts, freezing or pasteurisation or other processes that affect the food but do not add oils, fats, sugars or salts. | Eggs, milk, dried fruits, nuts, frozen or chilled or packed whole foods, fresh and dried herbs and spices, flakes and flours made from corn |
| NOVA 2 | Oils, fats, salt and sugar. Products extracted from natural foods by processes such as pressing, grinding, crushing or refining. Used for seasoning. | Honey, vegetable oils, coconut oil, butter, lard, maple syrup |
| NOVA 3 | Processed foods manufactured by industry with the use of salt, sugar, oil or other substances (Group 2) added to natural or minimally processed foods (Group 1) to preserve or to make them more palatable. They are recognised as versions of the original food, generally containing two or three ingredients. | Canned or bottled legumes in vinegar or pickling, tomato paste, bacon, freshly made cheese, canned fish, cured meat, freshly made bread unpackaged, beer |
| NOVA 4 | Ultra-processed foods are industrial formulations made entirely or mostly from substances extracted from foods (oils, fats, sugar, starch and proteins), derived from food constituents (hydrogenated fats and modified starch) or synthesised in laboratories from food substrates or other organic sources (flavour enhancers, colours and several food additives) | Chocolates, cakes, candies, fizzy drinks, chicken nuggets, pre-prepared pizza, breakfast cereals and bars, sweetened yogurts, packaged breads, margarine |

Food waste cannot be avoided totally or changed due to inedible parts [19,20]; however, when it comes to edible food waste, there is potential for positive change. Food waste can be separated into categories: unavoidable (inedible), potentially avoidable and avoidable (edible) food waste [19,20]. In the present study, 'avoidability' (Table 2) was used to refer to these categories. Furthermore, to conceptualise the generation of consumer food waste, three categories from a theoretical framework were applied: preparation and serving, consumption and storage [12]. In the present study, the 'food waste generation phase' (Table 2) identifies these categories.

The aim of this research was to explore food waste and how it may relate to dietary health. This study therefore evaluated the type and amount of food waste at the household

level to understand any relationships between household characteristics, the type of food that is discarded and level of food processing involved in the discarded food.

Specifically, this study sought to determine:

1. What links exist between nutritional quality and food waste; specifically, is the NOVA classification of a food item associated with categories of food waste in households, such as avoidability or the food waste generation phase, i.e., preparation, consumption or storage?
2. Are household characteristics such as educational attainment, household income and household size associated with categories of avoidable, potentially avoidable and unavoidable food waste?
3. Are household characteristics such as household size, educational attainment and household income associated with food waste by NOVA classification?

**Table 2.** Categories applied to food waste analysis.

| Food Waste Category | Food Waste Category Definitions |
| --- | --- |
| Avoidability: Avoidable, Unavoidable and Potentially Avoidable | To categorise food waste as avoidable, unavoidable and potentially avoidable, seminal definitions were used [19,20]. Potentially avoidable was further defined to include food with parts easily incorporated within a standard meal or turned in compote, soup or a smoothie, e.g., apple cores, pear cores, carrot peel and ends, broccoli stalk, heart of cabbage, ends of leeks, ends and centre of bell pepper, used chilli peppers and potato peel. Dry onion peel or garlic peel, citrus peel, banana peel, tea and coffee leftovers, eggshells and bones were all classed as unavoidable, as none of these foods could be categorised as potentially avoidable. |
| NOVA: NOVA 1, NOVA 2, NOVA 3 and NOVA 4 | To categorise food as processed or unprocessed, the NOVA tool was used and the definitions of NOVA applied (Table 1). |
| Food waste generation phase: Preparation and Serving/Consumption/Storage | For the food waste generation phase: the framework and descriptions from the literature on preparation and serving, consumption and storage were used to categorise the data according to the photographs [12]. |
| Food Group: Vegetables/Drinks/Bakery/Meals/Dairy/Eggs/ Fruit/White Meat/Red Meat/ Seafood/Processed Vegetables/Sweet/Oil/ Condiments/Staple/Breakfast Cereal/Confectionery/Processed Fruit/Other | For the food group, the same categories and definitions used by WRAP were used as the data collection methods were similar (i.e., hand-written diary) to the current study [19,20]. One difference in the current study was the creation of a new category 'Breakfast Cereal', rather than coding this under 'Staple', as breakfast cereals were frequently mixed with milk. |

## 2. Materials and Methods

### *2.1. Selection of Data Collection Methods*

To assess the complex picture of household food waste, clear guidance on feasible methods for measuring food waste are required [21]. The Circular Economy Action Plan set out the EU's ambitions to develop a sustainable economy by minimising waste and valuing resources, proposing that all member states measure their food waste and report annual estimates of food waste, alongside using more precise and robust direct food waste measurement methods, every four years [22]. Despite this initiative, reliable and comparable data along the supply chain are lacking due to inconsistent definitions, monitoring and reporting [23]. Various methods have been used to audit food waste [24], including the quantification of residual municipal waste, food waste diaries, photographs and qualitative research [25]. Due to the high costs of measuring household food waste directly, many studies have used self-assessed questionnaire methods [26]. There have been a number of initiatives to improve the quality of measuring household food waste [27–29]. However, there remain few primary data studies on household food waste [30,31]. The methods selected to measure the quantity of food waste depend on the purpose; understanding the nature of household food waste necessitates composition-specific data, whilst tracking progress in relation to targets requires data at scale but with less detail [28]. For the present

study, a range of research methods were considered. Weight compositional analysis, despite being a direct method for assessing food weight, was not selected as it was important to easily categorise the foods into NOVA 1, 2, 3 and 4 (Table 1) and the food degradation that inevitably occurs in food waste caddies would make this impossible. A questionnaire method was not selected as this method has been frequently used by the Waste and Resources Action Programme (WRAP) in the UK [32,33] and has been deemed less reliable due to the limitations of self-reporting [31,34]. A number of studies relating to household food waste have used handwritten diaries to measure food waste amounts [25,35–38], and written diaries, kitchen caddies and photograph coding measures correlate strongly [34]. The method of photographic diaries was selected for the present study, as the coding of photographs of food waste as a measurement can provide valid measures [31,39]. Usefully, the photographic diary method reduces the burden on participants (in comparison with a handwritten diary) and can thereby improve the retention of participants in a study [31,34]. Thus, this method is well-suited to citizen science [40], which was preferred in order to capture data relating to daily activities in the household. Additionally, the photographic diary method provided a way of assessing the volume of wasted food, offering an opportunity to acquire data in the form of weight estimates. Using photographs to quantify food waste does incur substantial effort in data handling due to the time required for coding photographs [41]. The photographic diary method has been used in the context of food waste relating to school and university canteens, although these settings restricted the photographs to plate waste [42,43]. Photographs have also been used in qualitative research on household food waste in relation to food storage or food habits in the home as part of ethnography and other qualitative studies [44–46] and have been used successfully in similar but different contexts, i.e., child nutrition, home energy usage and plastic recycling studies [47,48].

### *2.2. Study Area, Participant Recruitment and Data Collection*

The county of Hampshire was selected based on its ability to represent a relatively affluent county in the UK and other affluent regions in high-income countries. Recruitment occurred across all ten districts in Hampshire, UK to ensure a diverse geographical spread and demographics by convenience sample. We reasoned that only individuals wanting to complete a photographic diary would participate, which surpassed the strategy used to recruit. Convenience sampling is also an established method in peer-reviewed research in this field [25,49–51]. As the study required some demands on time from participants, self-selection was deemed the most suitable method to avoid the early drop-out of participators or incorrect reporting due to fatigue or lack of engagement with the study.

Potential respondents were recruited via social media (Facebook) and in targeted public locations where flyers were displayed. The advertisement was posted in each district of Hampshire on a Facebook group for the general community, the local council, a local food bank and a green community group; from here, the advertisement was further shared with local networks. In total, approximately eighty advertisements were shared on Hampshire Facebook groups and seven advertisements were shared in local newsletters. The advertisement was also posted in fast food outlets and food banks in Hampshire. The advertisement stated the study topic and its purpose, inviting participants to engage with the study either by email, text or phone call and included the incentive of a £10 (UK) voucher. The inclusion criteria for the study were that all participants were required to be adult residents aged 18 and above who buy and prepare food and who living in a private household, i.e., a non-institutional setting, in Hampshire UK. Once each respondent had self-selected to learn more about the study, they were screened according to the inclusion criteria and, if eligible, sent a participant information sheet and a consent form electronically. In total, 126 individuals self-selected, of whom 95 consented to be part of the study.

Participants received written and photographic instructions on the definition of food waste adopted for the study. Participants were asked to take a photograph of every item of edible or inedible food that was thrown in the bin, composted, disposed of down the drain

or given to pets in their household. Images were captured over seven consecutive days between 15th and 28th of November 2021 alongside a photograph of their hand (providing the length of their hand from tallest finger to wrist) or a ruler for scale. Participants were also given the option to weigh the food waste in each photograph using scales available at home. Each participant and the researcher formed a WhatsApp group of two members to share the photographs. WhatsApp was selected as it is an encrypted app for image, text, audio and video messaging; all communication had end-to-end encryption and was GDPR compliant. The WhatsApp data were archived on the secure University of Southampton server. Throughout the collection of data, the researcher stayed in contact with each participant over WhatsApp, asking for clarification on any unclear pictures and ensuring participants remained engaged in the study. Alongside the food waste photographic diary, each participant also completed a telephone survey with the researcher to collect data on food insecurity and socio-demographics, i.e., age, nationality, gender, average household income, household size and highest educational attainment in the household. Of a sample of 95 participants who initially consented to be part of the study, 94 fully completed the data collection.

### *2.3. Data Processing*

Food waste per household was calculated in accordance with prior research [12,18–20]. The food waste data recorded for each photograph comprised categories of food type and stage (Table 2). All data were collated onto a database and associated with a unique ID representing each participating household.

Every photograph was assessed visually to estimate the volume (by measure of scale contained in the photograph) and/or the weight of food waste (by direct weighing of the food observed in the photograph). Two tools were used to assist the visual estimate, a novel library of standard photographs and the FAO/INFOODS Density Database [52]. Examples of food waste photographs with details on how they were analysed are included in Supplementary Materials (Table S1). The library of standard photographs was created by using photographs of various foods with avoidable and unavoidable parts with associated actual weights as weighed by the researcher and/or participants during the study. This tool supplemented the FAO/INFOODS Density Database, which has some limitations in terms of the foods listed [52]. For foods included in the FAO/INFOODS Density Database, a volume estimate of the food waste was made using the photograph measure of scale [52]. The volume estimate was multiplied by the density unit to derive a weight [25]. The FAO/INFOODS Density Database was notably useful for estimating the weight of meals with mixed foods or mixed vegetables [52]. For the purposes of the present study, a mean value of all the vegetable density units was calculated and applied to photographs that included mixed vegetables. Similarly, for meals with mixed foods, a mean value of all the mixed meals density units was calculated and applied to photographs that included mixed meals. For food items in their packaging, weights were clarified and estimated using the suppliers' websites.

### *2.4. Quantitative Data Analysis*

The data were grouped by household. The food waste weight was calculated and stratified by key variables: NOVA (Table 1), avoidability (Table 2), food waste generation phase (Table 2), household size (Table 3), educational attainment (Table 3) and average household income (Table 3). In SPSSv26 (IBM Corporation), a Shapiro–Wilk test of normality was conducted to determine whether food waste weight by household for the categories of NOVA, avoidability and food waste generation phase data were normally distributed [53]. The results concluded that each set of data were not normally distributed. Thus, non-parametric statistical tests were applied in all cases. Data were analysed using a Kruskal–Wallis H test (SPSSv26; IBM Corporation) to determine the significance of variation between the medians of specified independent groups. This test was selected as there were three or more groups to compare and the data in each group were continuous variables [53]. For Kruskal-Wallis

H test statistics demonstrating a significant effect (at the 0.05 level), pairwise comparison tests and Bonferroni correction were run [53].

**Table 3.** Demographics of Sample Participants and Hampshire.

| Demographic | Demographic | Sample (n) | Percentage (%) | Hampshire Percentage or Average |
|---|---|---|---|---|
| Gender | Female<br>Male | 83<br>11 | 88.3<br>11.7 | 51.1%<br>48.9%<br>[54] |
| Number of people in a household | 1<br>2<br>3<br>4<br>5+ | 17<br>31<br>16<br>28<br>2 | 18.1<br>33.0<br>17.0<br>29.8<br>2.1 | Average household size 2.4. [55] |
| Household income (relative to £29,900 p.a.) | Lower<br>Higher<br>About median level<br>No response | 20<br>65<br>8<br>1 | 21.3<br>69.1<br>8.5<br>1.1 | Average earnings in Hampshire £32,500 p.a.<br>[56] |
| Household education | NVQ, A and AS Level, GCSE or equivalent<br>University degree<br>Postgraduate studies | 10<br>29<br>55 | 10.6<br>30.9<br>58.5 | 29.7% have level 4 qualification and above (degree level or above)<br>[55] |
| Ethnicity | White, UK and Ireland<br>White, not UK and Ireland<br>Not white | 81<br>7<br>6 | 86.2<br>7.4<br>6.4 | 91.8%<br>3.2%<br>5.0%<br>[55] |
| Household tenure | Mortgage/own<br>Rent<br>Other | 73<br>18<br>3 | 77.7<br>19.1<br>3.2 | 71.5%<br>26.3%<br>2.1%<br>[55] |
| Households with children (Under 18) | Partner and child/children<br>My children | 43<br>4 | 45.7<br>4.3 | 27.9%<br>Lone parent 8.7%<br>[55] |
| Age | 18–34<br>35–49<br>50–64<br>65+ | 22<br>45<br>20<br>7 | 23.4<br>47.9<br>21.3<br>7.4 | 23.2<br>23.5<br>26.2<br>27.1<br>[54] |

## 3. Results

The participants in the present study had a broadly similar representation regarding household size, household income, ethnicity and housing tenure to the Hampshire average (Table 3). However, there were differences in representation regarding gender, education, number of families with children and age of participants. The majority of the 94 respondents participating in the research were female (88.3%), compared with 51% for Hampshire (Table 3) [54]. The highest proportion of respondents were aged 35–49 (47.9%), and the smallest proportion were persons over 65 years of age (7.4%); those 18–34 represented 23.4% and 50–64 represented 21.3%.

The highest educational attainment for respondent households was postgraduate degree (58.5%), followed by university degree (30.9%). This differed to the Hampshire average of 29.7% acquiring qualifications to degree level or above [55]. Within the survey sample, the average size of households was 2.7 persons, which is similar to the Hampshire average of 2.4 [55]. The study included a proportion of households living with a partner and child or children that was higher than the Hampshire average: 45.7% in comparison with 27.9% [55]. The ethnicity of the sample was primarily UK and white (n = 81) or white

not UK and Ireland (n = 7). In the participant sample, 21.3% of households reported an annual income lower than £29,900 and 69.1% reported one that was higher. Meanwhile, the average household annual earnings in Hampshire is £32,500. Of the participants, 77.7% owned or had a mortgage on their property, while 19.1% rented and 3.2% had other arrangements; these statistics are similar to Hampshire averages of 71.5%, 26.3% and 2.1%, respectively [55].

Of the participant sample, 94.7% reported never to all questions on experiencing food insecurity over the last year, while 5.3% stated that sometimes in the last 12 months "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more." Government data from fiscal year ending in 2020 of households in the UK reported that 92% of households were food secure, 4% reported low food security and 4% very low food security [57].

### *3.1. Food Waste in Relation to NOVA and Avoidability Category*

Data from 94 households indicated that the majority of food waste was in the NOVA 1 category (Table 4) and that it was fairly evenly split between avoidable, potentially avoidable and unavoidable food waste. Of the total food waste, 11% was in the NOVA 4 category and was avoidable.

**Table 4.** Total weights and proportions of food waste for all participating households (n = 94) in relation to NOVA category (Table 1) and avoidability (Table 2) over 7 days.

| | Avoidable Food Waste (g) | Potentially Avoidable Food Waste (g) | Unavoidable Food Waste (g) | Proportion of Avoidable and Potentially Avoidable Waste by NOVA | Proportion of Total Food Waste by NOVA |
|---|---|---|---|---|---|
| NOVA 1 | 71,896 (31%) | 47,174 (20%) | 85,693 (36%) | 51% | 87% |
| NOVA 2 | 294 (0%) | 61 (0%) | 0 (0%) | 0% | 0% |
| NOVA 3 | 3517 (2%) | 29 (0%) | 113 (0%) | 2% | 2% |
| NOVA 4 | 26,698 (11%) | 11 (0%) | 23 (0%) | 11% | 11% |

### *3.2. Food Waste in Relation to NOVA and Food Waste Generation Phase Category*

Table 5 shows that the majority of food waste occurred during the preparation phase and in the NOVA 1 category. Consumption and storage were the least significant waste generation phases for NOVA 1 food, though, overall, the amount of food waste was still higher in both of these categories than for NOVA 4 food waste.

**Table 5.** Total weights of food waste for all participating households (n = 94) in relation to food waste generation phase (preparation, storage, consumption or unclear; Table 2) and NOVA category (Table 1) over 7 days.

| | Food Waste during Preparation (g) | Food Waste during Storage (g) | Food Waste during Consumption (g) | Unclear (g) | Proportion of Total Food Waste by NOVA |
|---|---|---|---|---|---|
| NOVA 1 | 142,812 (61%) | 37,147 (16%) | 24,183 (10%) | 622 (0%) | 87% |
| NOVA 2 | 80 (0%) | 225 (0%) | 0 (0%) | 50 (0%) | 0% |
| NOVA 3 | 198 (0%) | 2259 (1%) | 1186 (1%) | 16 (0%) | 2% |
| NOVA 4 | 1083 (0%) | 11,036 (5%) | 14,573 (6%) | 40 (0%) | 11% |
| Total | 144,173 (61%) | 50,667 (22%) | 39,942 (17%) | 728 (0%) | 100% |

A Kruskal–Wallis test demonstrated a significant effect in terms of food waste weight by food waste generation phase: Kruskal–Wallis H 102.570, $p < 0.000$. Post-hoc analyses (Dunn's multiple comparison tests) were conducted to test pairwise comparisons; food waste was found to occur in statistically significantly greater amounts due to preparation compared with storage ($p < 0.000$, Bonferroni correction $p = 0.000$) and consumption ($p < 0.001$, Bonferroni correction $p = 0.000$). Food waste quantities associated with storage and consumption were not significantly different ($p = 0.249$, Bonferroni correction $p = 0.748$).

### *3.3. Household Characteristics i.e., Household Size, Educational Attainment and Average Household Income in Relation to Food Waste by Avoidability Category*

In relation to household size, the findings showed that on average, over seven days, people from households of four or more wasted more food per person than households of two or three (910 g, 763 g and 866 g, respectively) and that households of one wasted the most food per person (1353 g) (Table 6). However, households of four or more had the most unavoidable food waste and the least potentially avoidable food waste per person (369 g and 163 g, respectively) (Table 6). Regarding avoidable food waste, one person households wasted the most (688 g), followed by households of three (489 g) and households of four or more (378 g) (Table 6). Descriptive statistics on the variances between households in each household size group are included in the Supplementary Materials (Table S2).

**Table 6.** Avoidable, unavoidable or potentially avoidable food waste (Table 2) in relation to household size, educational attainment and average household income (Table 3) per person over seven days.

| Category | Sub-Category | Avoidable Food Waste (g) | Unavoidable Food Waste (g) | Potentially Avoidable Food Waste (g) | Average Total Food Waste (g) |
|---|---|---|---|---|---|
| Household Size | 1 | **688** | **360** | 305 | 1353 |
| | 2 | **192** | **364** | 207 | 763 |
| | 3 | **489** | **207** | 170 | 866 |
| | 4 or more | **378** | **369** | 163 | 910 |
| Highest educational attainment in the household | Postgraduate | 339 | 328 | **182** | 849 |
| | University degree | 475 | 369 | **293** | 1138 |
| | Below degree level | 440 | 303 | **71** | 814 |
| Average median UK household income in 2020 £29,900 p.a. | Higher | 320 | 352 | 213 | 885 |
| | About median level | 194 | 325 | 285 | 804 |
| | Lower | 701 | 286 | 151 | 1138 |

Note: All household data (n = 94) were normalised per person per week and all data were normalised by number of households in each category. Categories demonstrating statistical significance in terms of the Kruskal–Wallis H test statistic are in bold.

Kruskal–Wallis tests were run to explore the significant differences between the medians of avoidable, potentially avoidable and unavoidable food waste in relation to household sizes of one, two, three and four or more (Table A1; Appendix A). Significant differences for household size in relation to avoidable and unavoidable food waste were identified. Post-hoc analyses (Dunn's multiple comparison tests) were conducted to test pairwise comparisons. Avoidable food waste was statistically significantly higher in households of one, three and four or more people than in two person households: ($p$ = 0.003; Bonferroni correction $p$ =0.019), ($p$ = 0.003; Bonferroni correction $p$ =0.014) and ($p$ = 0.009; Bonferroni correction $p$ = 0.055), respectively (Table A1; Appendix A). Unavoidable food waste was significantly higher in households of two than in households of three ($p$ = 0.009); however, when this value was adjusted by Bonfferoni correction it was close to but no longer at the level of 0.05 statistical significance ($p$ = 0.057) (Table A1; Appendix A). The remaining results showed that once significance values had been adjusted for the Bonferroni correction for multiple tests, unavoidable food waste was not significantly different between other household sizes.

Observations indicated that, over seven days, per person, the most avoidable food waste occurred in the group educated to university degree level (475 g), followed by the group with below degree level qualifications (440 g) and the group with postgraduate qualifications (339 g) (Table 6). Potentially avoidable food waste was lowest per person in the below degree level group (71 g) and highest in the university degree group (293 g) (Table 6). Overall food waste was greatest per person for the university degree group (1138 g), while the postgraduate and below degree level groups were similar (849 g and 814 g, respectively) (Table 6). Descriptive statistics on the variances between households in each educational attainment group are included in Supplementary Materials (Table S2).

Kruskal–Wallis tests determined significant differences between groups of different education level for potentially avoidable food waste (Table A1; Appendix A). Post-hoc Dunn's multiple comparison tests were conducted for pairwise comparisons. Potentially avoidable food waste occurred in statistically significantly greater amounts in the postgraduate and university degree groups than in the below degree group: ($p$ = 0.009; Bonferroni correction $p$ = 0.026), ($p$ = 0.008; Bonferroni correction $p$ = 0.025), respectively (Table A1; Appendix A).

Regarding average household income, avoidable food waste was greater per person for lower income households (701 g) in comparison with higher income households (320 g) (Table 6). Unavoidable and potentially avoidable food waste weight was lower per person for lower income households than for higher income households (286 g and 151 g compared with 352 g and 213 g, respectively) (Table 6). Overall, the total average amount of food waste per person per week was higher in lower income households than in higher income households (885 g and 1138 g, respectively) (Table 6). None of these differences, however, were found to be statistically significant (Table A1; Appendix A).

### *3.4. Household Characteristics, i.e., Household Size, Educational Attainment and Average Household Income in Relation to Food Waste by NOVA Category*

For all household sizes, the majority of waste occurred in the NOVA 1 category. One-person households wasted the most food per person in the NOVA 1 category (1190 g) and households of four or more, three and two people wasted similar amounts per person (801 g, 763 g and 787 g, respectively) (Table 7). Households of four or more people wasted the most NOVA 4 food per person (129 g) (Table 7). Kruskal–Wallis tests established that there were no significant differences between food waste by NOVA category across groups of different household sizes (Table A2; Appendix B).

**Table 7.** NOVA category (Table 1) of food waste in relation to household size, educational attainment and average household income per person over seven days (Table 3).

| | | NOVA 1 Food Waste (g) | NOVA 2 Food Waste (g) | NOVA 3 Food Waste (g) | NOVA 4 Food Waste (g) |
|---|---|---|---|---|---|
| Household size | 1 | 1190 | 0 | 46 | 128 |
| | 2 | 787 | 1 | 12 | 58 |
| | 3 | 763 | 5 | 14 | 101 |
| | 4 or more | 801 | 1 | 12 | 129 |
| Highest educational attainment in the household | Postgraduate | 790 | 1 | 16 | 93 |
| | University degree | 1037 | 3 | 26 | 118 |
| | Below degree level | 738 | 0 | 11 | 92 |
| Average median UK household income in 2020 £29,900 p.a. | Higher | 815 | 2 | 13 | 93 |
| | About median level | 896 | 2 | 0 | 76 |
| | Lower | 984 | 0 | 45 | 141 |

Note: All household data (n = 94) were normalised per person per week, and all data were normalised by number of households in each category.

In relation to all educational attainment categories, the majority of food waste was in the NOVA 1 category. The most food waste in NOVA 1 and NOVA 4 occurred per person in the university degree group (1037 g and 118 g, respectively). The post graduate group and below degree level group wasted similar amounts per person of NOVA 1 (790 g and 93 g) and NOVA 4 (738 g and 92 g) (Table 7). Kruskal–Wallis tests established there were no significant differences between food waste by NOVA category across groups in terms of educational attainment (Table A2; Appendix B). The amounts of NOVA 1 food waste were similar in all household income groups but highest in the lower income group (984 g) (Table 7). The waste of NOVA 4 food was similar across all income groups but greatest in the lower income group (141 g) (Table 7). Kruskal–Wallis tests determined that there were no significant differences in terms of food waste by NOVA category across groups of average household income (Table A2; Appendix B).

## 4. Discussion

After extrapolation, the food waste amount per person per year for the current study was equivalent to 48.62 kg. This amount was similar to the 44.6 kg per person per year calculated from a recent household kitchen diary study in Germany including edible and inedible food waste from a representative sample of 6853 households [36]. Other household kitchen diary studies on food waste have reported lower values, but observations are broadly similar as they only pertained to avoidable food waste: 27.5 kg per person per year (an Italian study of 385 households) [35] and 23 kg per person per year (a Finnish study of 380 households) [37]. Although the current study captured similar amounts of food waste to other kitchen diary studies, it differs from household food waste quantification methods using other disposal pathways and waste composition analyses in Europe. For example, in the UK, it was calculated that household food waste was 108 kg per capita per year [33]. A comprehensive review on household food waste quantification methods concluded that there is no 'one best' method of food waste quantification at household level, rather it depends on the study objective, which in the current study placed importance on the composition of food waste, lending to the strength of the kitchen diary method [21].

The majority of all food waste was in the NOVA 1 category (87%) and during the preparation stage (61%) (Tables 4 and 5). Analysis showed that significantly greater quantities of food waste occurred during preparation than during the storage and consumption phases. An explanation for the majority of NOVA 1 food waste occurring in the preparation phase may be that NOVA 1 food generally presents an inedible and edible component defined by cultural and individual differences [19]. To reduce the loss of unprocessed foods, a focus on interventions during the food preparation phase that addresses cultural and social norms in demonstrating how to minimise loss of edible components (e.g., ends of courgettes and skins of mushrooms) would have merit.

Of the total food waste, 51% was NOVA 1 and either avoidable or potentially avoidable. There is thus the opportunity for big gains in reducing unprocessed food waste. This includes important components of a diet high in fresh produce, providing nutrients including fibre [14]. Currently, the UK is not reaching the recommended levels of fruits and vegetables or fibre [14] contained in NOVA 1 foods. A number of NOVA 1 foods are relatively cheap (e.g., carrots and potatoes), and therefore it may be that consumers feel more relaxed about wastage. Additionally, it requires time, organisation and expertise to prepare food in the NOVA 1 category [58,59]. Time and organisation may be more challenging to manage in certain households in comparison with others. A recent study of 4214 consumers across five European countries concluded that lifestyle patterns regarding food are linked to variations in food waste and the choice of suboptimal food, contributing to an understanding of differences in food waste amounts by household [60]. The study clustered certain households into the 'well-planning cook and frugal food avoider' that reported generating less food waste [60]. In contrast, households described as 'uninvolved with food and not focused on price' (thus not organising or investing time in food waste reduction behaviours) reported generating more food waste; another group were described as food uninvolved but focused on price and preferred convenience food, with this group tending to report generating lower amounts of food waste (the focus on price indicated a degree of organisation and time invested here) [60]. Ultimately, the values upheld by the household may dictate the amount of organisation and focus devoted to food management and affect food waste.

Prior research has shown a linear trend towards food waste amounts and household size [36,61,62]. However, relatively few studies have analysed household size in relation to the per-person food waste generated. In this regard, studies show mixed outcomes, with certain studies showing a linear trend [62] and others not [63,64]. A study of household food waste in Denmark using a self-reported survey demonstrated that there were statistically significant relationships (at the $p < 0.01$ level) between household sizes and a range of pertinent variables concerning food waste generation [65]. A further study indicated that single person households in Denmark generated higher avoidable food waste than those

containing two persons, three persons and more than three persons, though this difference was not statistically significant, thereby suggesting that there was no significant difference per person [64]. A kitchen diary study in Finland showed that the influence of household size resulted in differences between households with one person and those with five or more people ($p < 0.100$) when the dependent variable was waste per capita, but otherwise there was no significant difference [63].

The present study showed that households of two persons wasted less food per person than households of other sizes did, indicating a potentially greater need for interventions to focus on households of one, three and four or more. This observation was statistically significant. An explanation for this may include a reduced logistical burden or less indication of convenience-oriented waste management strategies in small households (e.g., two-person households) in contrast to larger households, as they were more likely to report disposing of food waste in the garbage stream (rather than the organics stream; $p = 0.032$) [62]. Smaller households, for example, have fewer dependents such as children putting demands on time, with unpredictable behaviour, or fewer scheduled work, school or extra-curricular activities [66]. In contrast to a one-person household, a two-person household can share the organisational load in terms of managing food at home, possibly improving organisation and planning and thereby increasing the use of efficiency measures. Additionally, if a two-person household has a double income, this finance may add extra options regarding food choice, storage or cooking facilities that benefit food waste reduction. Certain studies of household food behaviours have indeed shown that two-person households may behave differently to households of different sizes [51,67–69]. These observations indicate a greater need, at least in the case study herein, for interventions to focus on households of one, three and four or more persons. We note that research findings with regard to the relationship between household size and food waste generation are not entirely consistent and that the outcomes of the present study may be specific to the research setting and participant group. Further research may be required to establish if and why two-person households differ from other household sizes in terms of food waste generation.

Unavoidable food waste was not significantly different between households of different sizes. Considering that 36% of all food waste in the current study was unavoidable, interventions to reduce or offset the environmental impact of food waste (e.g., food waste collection) would have merit, especially if supplied for all households. One way of increasing householders' engagement with food waste recycling is via nudges in terms of social norms or social norms and reminders or social norms and disclosure [70]. Conformity to social norms around food may be driven by increases in reward-related activity in the brain as behaviour streamlines with other people, which is consistent with the more general idea that reward is central to social conformity [71]. It has been shown that agreeing with the preferences and decisions of others activates psychological reward networks, while disagreement has the opposite effect [71]. Thus, food waste recycling interventions may incorporate this knowledge to achieve successful outcomes.

The influence of education was also explored in relation to food waste classified by NOVA category and avoidability. Overall, NOVA 1 was the most prevalent category of food waste across all educational groups, and differences in food waste between NOVA categories were not statistically significant. This observation indicates that the overwhelming issue of food waste is mostly in the unprocessed category for all households regardless of educational attainment (Table 7). Statistical analyses showed that potentially avoidable food waste occurred in statistically significantly greater amounts in the post-graduate and university degree groups in comparison with the below degree group. The highest level of education in the household thus appears to be a meaningful predictor of potentially avoidable food waste. These findings are different to a recent survey of 1518 Danish and 1511 Spanish consumers; in both of these countries, the education level was not associated with food waste behaviour [72]. This outcome was determined using a prediction model that created a comprehensive measure of food waste behaviour including self-reported food waste behaviour, e.g., planning routines, shopping routines and food preparation

practices combined with self-reported household food waste [72]. An explanation for the outcomes of this study could be that households where the highest educational attainment is at least a university degree may be buying more fruits and vegetables with potentially avoidable parts and/or buying less frozen or tinned NOVA 1 food that has a longer shelf life and requires minimal preparation, e.g., frozen peas or tinned sweetcorn. Previous studies have shown that pro-environmental behaviours and education level are linked [73], e.g., those with a higher level of education may consume a more plant-based diet which may have more potentially edible components or reduce packaging waste, i.e., they might not buy frozen vegetables due to plastic waste. However, perhaps the issue is that despite pro-environmental intentions, competence in this area and behaviours towards reduce food waste are lacking. This indicates a need for interventions to address this gap, particularly in households with educational attainment to degree or post-graduate level.

Although not statistically significant, avoidable food waste was greater per person for lower income households than for higher income households, and unavoidable and potentially avoidable food waste weights were lower per person for lower income households than for higher income households (Table A1; Appendix A). Explanations for wasting more avoidable food include difficulties in the portion sizing of meals, increases in intuitive eating, the desire not to overeat, a dislike of food or fussy children [10,17]. Greater avoidable food waste may also be explained by difficulties in terms of equipment and infrastructure at the household level or perceived control, expertise and skill at the individual level regarding food storage, preparation and consumption, perhaps driven in part by social structural differences external to the household [11]. Food waste in the NOVA 1 category may be disproportionately affected by structural differences which may be solved by a cross-organisational education approach in health, education and social care settings [59]. Increases in intuitive eating or a desire not to overeat, driven by health awareness, may be a greater factor for food waste in the NOVA 4 category [17]. These aspects merit consideration in the design of interventions that aim to reduce food waste and improve health.

Although the current study showed significant results regarding food waste and household demographics, it remains important to consider alternative approaches to interventions given that households differ due to a variety of internal and external factors [11]. Prior research has concluded there is value in focusing on foods that are most often wasted rather than custom-fitting interventions to household demographics [74]. Thus, there is, for example, merit in the waste composition data categorised by NOVA. An alternative approach could be to reinforce interventions by types of food waste aligned with NOVA 1, which may offer important health benefits while supporting food waste reduction and improving food security [59].

### *4.1. Implications*

The present study provides the basis for recommendations to be made for affluent regions in high-income countries, most specifically for populations who are environmentally and/or socially aware and have agency, to direct resources or programs to simultaneously reduce food waste and improve nutrition. It is recommended to focus on avoidable unprocessed food waste in the preparation and serving phase, especially for households of one, three or four+ persons. Additionally, a focus on interventions to reduce potentially avoidable food waste should be targeted towards those with householders educated to university degree level or higher. Strategies could encourage, for example, the use of unprocessed foods, especially fruit and vegetables that have a longer shelf life and are easy to prepare or are pre-prepared, such as tinned and frozen fruits and vegetables. The present study identifies opportunities to coordinate household food waste recycling for unavoidable and unprocessed food waste, e.g., coffee grounds and tea leaves. A potential added benefit to engaging householders in food waste recycling likely includes an increased awareness of the amount of household waste that comprises food [70]. In some cases, this information, learning and knowledge may be in part a driver for change to reduce food waste [75].

Photograph diaries using social media and smart phones was feasible and acceptable to the participants recruited (Table 3), as evidenced by the study's high participant retention levels (99% of consenting participants fully completed the study). This method enables the acquisition of objective and meaningful data that can be easily collected by participants as part of their daily routines. Additionally, the visual nature of the data collection means that language barriers may be circumvented [76]. The photographic diary method involved data entry that was time consuming for researchers but could be improved upon by simplifying the method, with improved instructions for participants, i.e., being more specific about participants providing photographs of foods separated by each category, e.g., recording images of fruit only, rather than mixed fruit and vegetable peelings. Furthermore, the photographic diary method could potentially be used alongside machine learning technology as a means to accelerate data capture [77–79].

The NOVA categorisation offers a simple and meaningful way to categorise food in terms of its value for health and provides useful data in a way that can be generated more easily to guide interventions [80]. Previous research has not used NOVA categories in relation to food waste as a way of identifying ultra-processed, processed, minimally processed and unprocessed foods that are discarded by householders without being consumed. Previous studies examining food waste and nutrition in the UK and Europe using primary data have provided a detailed analysis on the weights of specific nutrients such as vitamin C, B12 or fibre lost in food waste at home [80–82]. More broadly, such approaches have the potential to contribute to efforts to achieve global sustainability objectives, particularly SDG 12.3 (Responsible Consumption and Production) and SDG 2 (Zero Hunger). Strategies that simultaneously address both of these goals have clear merit in terms of efficiency and resource effectiveness. We recommend that 1. efforts to review and revise household food waste data may benefit from the addition of NOVA classification and 2. the photographic diary methodology is adopted more widely as a cost-effective measure of data capture [6]. These methods may also have value for the regular measurement of household food waste required as part of the EU circular economy action plan [22].

### *4.2. Limitations and Future Research*

The time frame of the study was limited to seven consecutive days; nonetheless, this timeframe was valuable as it included working days and weekends. There remains a risk that participants may have changed their general food waste behaviour in response to active participation in the study [28]. Additionally, as each household's profile was reported by one person, it was possible that food waste from others in the household may have been missed. However, as the same methods were used by all participants, the data offered patterns of food waste that were comparable, as all participants were limited in a similar way.

The demographics of the participant sample recruited to the research differed to the demographics of Hampshire with regard to gender, highest educational attainment, age and number of households with children. The majority of participants were female (Table 3), and this high female percentage may be related to how gender dynamics affect roles of food preparation in households or the social platforms used to recruit [83]. The number of participating households with the highest level of educational attainment level, postgraduate degree (Table 3), was higher than the Hampshire average [55]. This may be related to a correlation between level of education and environmental concerns, for example, surrounding food waste [66]. The smallest proportion of participants were aged over 65 years. The lower number of participants over 65 years may be related to the study advertisement or recruitment platforms, as only 34% of adults over 65 in the UK access social networking [84]. The highest proportion of participants were aged 35–49, with this possibly being linked to the high number of households with children recruited to the study. The study sample was greater than the Hampshire average regarding households living with a partner and child or children: 45.7% compared with 27.9% (Table 3) [55]. It is possible that this was related to families with children having more issues with food waste.

A review on household food practices showed that households with children generate more waste from meals given the unpredictable eating patterns and preferences of children alongside it being difficult to predict whether children will be eating at home at all [10]. It is important to highlight that the observations and outcomes of the present study do not necessarily apply to everyone everywhere but are specific to the study; the generalisation of these outcomes is unlikely to be robust. However, there is value in the categorisation of food waste data by NOVA, the demographic analysis of the results, the method of collecting data, and insights that would be useful for future research in other settings.

The participant sample largely selected all responses relating to never experiencing food insecurity on the food security survey (94.7%). However, the results offer insights for targeting food wastage in currently food-secure households, and, with rising costs of living [8], even households with a previously sufficient income may experience difficulties in affording food in comparison to previous years. For future research that includes more food insecure households, the current study will be useful as it showed that smartphones were acceptable for participants including those in lower income groups (21.3% of the sample) and those experiencing a level of food insecurity (5.3% of the participant sample answered yes to one relevant food insecurity question). For future research, smartphones with an internet connection could be loaned where needed. It may be that a greater financial incentive could be offered to make involvement in the research worthwhile for households experiencing food insecurity. In order to further research the linkages between food waste, food insecurity and diet quality, research on food waste patterns within populations specifically experiencing food insecurity would have value, especially if we are to develop sustainable food systems.

The present study suggests specific areas of food waste to target in households for maximum food waste reduction. To follow on from this, to understand how to tailor interventions for effective food waste reduction, future research into how personal values affect lifestyle patterns or household cultures in terms of food management and food waste would have merit. A future study leading on from the present one may involve predicting unavoidable and potentially avoidable food waste from secondary data, i.e., the NDNS report [14]. This could provide a measure of unavoidable food waste in the UK to understand requirements for food waste recycling. It could also provide an indication on a larger generalisable scale of how much potentially avoidable food waste arises in order to inform interventions targeting this problem.

## 5. Conclusions

In response to concerns regarding household food waste, diet quality and food insecurity in high-income countries, this study aimed to evaluate the type and amount of food waste at household level and by household characteristics. The study concludes that unprocessed foods form the largest portion of household food waste, particularly during preparation. Key focus points include a reduction in avoidable unprocessed food waste in one, three and four+ person households and a reduction in potentially avoidable unprocessed food waste in households with an educational attainment of at least a university degree. Solutions may include public health interventions encouraging healthy unprocessed food that require less preparation or are frozen. These interventions may become increasingly necessary in high-income countries where households with previously sufficient incomes may experience difficulties in budgeting for food in the face of increasing costs of living. Thus, targeted interventions to reduce food waste may provide an additional protective measure for food security and diet quality.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15032051/s1, Table S1: Examples of how the photographic data were classified; Table S2: Measure of variance: mean and standard deviation of household groups showing statistical significance.

**Author Contributions:** Conceptualization, H.B.; methodology, H.B.; formal analysis, H.B.; writing—original draft preparation, H.B.; writing—review and editing, H.B., D.M.S., P.J.S., B.R. and Z.C.; supervision, D.M.S., P.J.S., B.R. and Z.C.; project administration, H.B.; funding acquisition, H.B. and D.M.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** The research for this article was funded by the Economic and Social Research Council South Coast Doctoral Training Partnership (Grant Number ES/P000673/1).

**Institutional Review Board Statement:** The study was approved by the University Ethics Committee, reference number 66350.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data collected for this study are not available for distribution. To comply with requirements from the University Ethics Committee, the data are not publicly available due to ethical restrictions, and the PIS states that the data will not be shared.

**Conflicts of Interest:** The authors declare no conflict of interest.

## Appendix A

**Table A1.** Null hypotheses and test statistics for avoidable, unavoidable or potentially avoidable food waste (Table 2) in relation to household size, educational attainment and average household income (Table 3).

| Category | | Avoidable Food Waste (g) | Unavoidable Food Waste (g) | Potentially Avoidable Food Waste (g) |
|---|---|---|---|---|
| Household size | Null hypothesis | The distribution of avoidable food waste is the same across categories of household size | The distribution of unavoidable food waste is the same across categories of household size | The distribution of potentially avoidable food waste is the same across categories of household size |
| | Null hypothesis retained or rejected | Rejected | Rejected | Retained |
| | Kruskal–Wallis H | **Kruskal–Wallis H 14.088, $p$ = 0.003 *** | **Kruskal–Wallis H 7.922, $p$ = 0.048 *** | Kruskal–Wallis H 0.957, $p$ = 0.821 ** |
| Highest educational attainment in the household | Null hypothesis | the distribution of avoidable food waste is the same across categories of educational attainment | the distribution of unavoidable food waste is the same across categories of educational attainment | The distribution of potentially avoidable food waste is the same across categories of educational attainment |
| | Null hypothesis retained or rejected | Retained | Retained | Rejected |
| | Kruskal–Wallis H | Kruskal–Wallis H 0.461, $p$ = 0.794 ** | Kruskal–Wallis H 3.948, $p$ = 0.139 ** | **Kruskal–Wallis H 7.732, $p$ = 0.021 *** |
| Average median UK household income in 2020 £29,900 p.a. | Null hypothesis | The distribution of avoidable food waste is the same across categories of average household income | The distribution of unavoidable food waste is the same across categories of average household income | The distribution of potentially avoidable food waste is the same across categories of average household income |
| | Null hypothesis retained or rejected | Retained | Retained | Retained |
| | Kruskal–Wallis H | Kruskal–Wallis H 4.226, $p$ = 0.238 ** | Kruskal–Wallis H 2.069, $p$ = 0.558 ** | Kruskal–Wallis H 4.238, $p$ = 0.237 ** |

Note: each Kruskal–Wallis H test statistic was adjusted for ties; n = 94 households—data were normalised per person. Timeframe was 7 days. * demonstrating a significant effect. ** Multiple comparisons were not performed because the overall test did not show significant differences across samples.

## Appendix B

**Table A2.** Null hypotheses and test statistics for avoidable, unavoidable or potentially avoidable food waste (Table 2) in relation to household size, educational attainment and average household income (Table 3).

| Category | | NOVA 1 Food Waste (g) | NOVA 2 Food Waste (g) | NOVA 3 Food Waste (g) | NOVA 4 Food Waste (g) |
|---|---|---|---|---|---|
| Household size | Null hypothesis | The distribution of NOVA 1 food waste is the same across categories of household size | T=The distribution of NOVA 2 food waste is the same across categories of household size | TYhe distribution of NOVA 3 food waste is the same across categories of household size | The distribution of NOVA 4 food waste is the same across categories of household size |
| | Null hypothesis retained or rejected | Retained | Retained | Retained | |
| | Kruskal–Wallis H | Kruskal–Wallis H 2.404, $p$ = 0.493 ** | Kruskal–Wallis H 4.088, $p$ = 0.252 ** | Kruskal–Wallis H 1.482, $p$ = 0.687 ** | Kruskal–Wallis H 6.356, $p$ = 0.095 ** |
| Highest educational attainment in the household | Null hypothesis | The distribution of NOVA 1 food waste is the same across categories of educational attainment | The distribution of NOVA 2 food waste is the same across categories of educational attainment | The distribution of NOVA 3 food waste is the same across categories of educational attainment | The distribution of NOVA 4 food waste is the same across categories of educational attainment |
| | Null hypothesis retained or rejected | Retained | Retained | Retained | |
| | Kruskal–Wallis H | Kruskal–Wallis H 0.780, $p$ = 0.677 ** | Kruskal–Wallis H 0.972, $p$ = 0.615 ** | Kruskal–Wallis H 1.731, $p$ = 0.421 ** | Kruskal–Wallis H 1.098, $p$= 0.577 ** |
| Average median UK household income in 2020 £29,900 p.a. | Null hypothesis | The distribution of NOVA 1 food waste is the same across categories of average household income | The distribution of NOVA 2 food waste is the same across categories of average household income | The distribution of NOVA 3 food waste is the same across categories of average household income | The distribution of NOVA 4 food waste is the same across categories of average household income |
| | Null hypothesis retained or rejected | Retained | Retained | Retained | |
| | Kruskal–Wallis H | Kruskal–Wallis H 1.958, $p$ = 0.376 ** | Kruskal–Wallis H 2.176, $p$ = 0.337 ** | Kruskal–Wallis H 3.505, $p$ = 0.173 ** | Kruskal–Wallis H 0.763, $p$ = 0.683 ** |

Note: each Kruskal–Wallis H test statistic was adjusted for ties; n = 94 households—data were normalised per person. Timeframe 7 days. ** Multiple comparisons were not performed because the overall test did not show significant differences across samples.

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