



Understanding food waste generation in school canteens

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ABSTRACT

Reducing food waste across food supply chains is crucial for achieving global environmental goals, but the impact of organisational strategy and social factors on food waste in public catering is not well understood. This study aimed to quantify and explain the drivers of food waste in Swedish school canteens by analysing data at three levels: the organisational, the school, and the individual level. The analysis combined national survey data ($n = 111$ municipalities), school-level quantification data ($n = 693$ schools), and 1722 individual on-site observations. The results show that municipalities with a higher share of guests eating in production kitchens had lower food waste (Spearman's $\rho = -0.23$) while having an explicit food waste reduction goal did not affect food waste levels (45 vs 47 g per guest). At the school level, student age was moderately correlated with plate waste (Kendall's $\tau = 0.34$), with older students wasting about twice as much food as younger ones (36 vs 18 g per guest). At the individual level, extroverted students and those in group settings generated more waste (on average 67 g per waster). The findings point to complementary roles of organisational factors and guest behaviour in shaping food waste generation, highlighting the potential of interventions that address both.

1. Introduction

Reducing food waste is one of three major strategies for keeping the food system within the planetary boundaries (Springmann et al., 2018; Willett et al., 2019). Reducing food waste is also acknowledged in the United Nations Sustainable Development Goals (SDGs), which state that food waste should be halved by 2030 (United Nations, 2015), and has been highlighted as a key aspect to fulfilling obligations in the Paris Agreement (You et al., 2022).

When seeking to reduce food waste, it is important to know the baseline and possible causes of waste. Food waste data are currently scarce, but critical in order to understand the problem better (Xue et al., 2017). To drive developments in food waste reduction, the European Union (EU) requires all Member States to quantify food waste since 2020 and report national levels for the first time by mid-2022 (European Commission, 2019). The revised version of the European Waste Framework Directive also calls on Member States to reduce food waste levels and report progress (European Commission, 2018), ambitions that align well with the overarching SDG to halve food waste by 2030. The consumption stage of the food supply chain comprises households, retail and the food service sector (Stenmarck et al., 2016). Food waste at this stage means that more value is lost, since resources are accumulated for every previous step in the food supply chain (FAO, 2013). Global estimates of food waste indicate that households are the largest contributor (589 Mt),

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followed by the food service sector (244 Mt) and retail (118 Mt) (United Nations Environment Programme, 2021). Thus, while current global estimates indicate that households generate most waste, the food service sector is still an important contributor. The food service sector comprises actors who are all obliged to follow the same types of directives and legislation, although the sector itself is diverse and covers a wide range of sub-actors (such as major chains, small privately-owned businesses and public catering establishments).

In Sweden, the food service sector has a particularly distinct structure, as all school children are entitled by law to free school meals financed through municipal taxation. Municipalities are responsible for organising these meals, most often through a combination of production kitchens, which prepare meals on-site, and satellite kitchens, which receive food prepared elsewhere. Meals are typically served in a self-service buffet system, where guests select their own portions from a shared serving line. Food waste is generated at several points in this system, most notably in the kitchen (overproduction and preparation losses), at serving (buffet leftovers), and on the plate (uneaten food discarded by students). Many of the municipalities also collect and report data on food waste within this sector, providing a rare degree of transparency compared to many other countries. These institutional arrangements shape both opportunities and challenges for food waste prevention and reduction and thus form the backdrop against which the present study is situated.

Successful waste reduction measures implemented in relatively few places in the food service sector could have a large impact. Previous food service sector studies have indicated that food waste can be up to 15 g/guest or 980 g/sale (Abdelaal et al., 2019; Juvan et al., 2017; Malefors, 2022). There are also suggestions that waste levels can show large variation between different canteens within the same organisation. For instance, Eriksson et al. (2017) found that food waste levels in the best-performing canteens was only 25 % of that in canteens with most food waste within the same organisation.

Consumer food waste in a canteen setting is significantly influenced by the surrounding environment (Filimonau and Coteau, 2019). This environment is shaped by organisational structures and policies, and by social dynamics and interactions with consumers and staff. Within this setting, numerous factors affect individual decisions to waste food, creating a complex web of influences (Lévesque et al., 2024).

Previous studies on food waste in canteens and kitchens have identified two main categories of influence: infrastructural or organisational elements and the behaviour of staff and consumers, including their meal patterns. For instance, research by Byker et al. (2014) suggests that portion size, ambient noise, mealtime duration and student age are key determinants of food waste in American primary schools. Similarly, age has been identified as a factor in food waste in educational settings (Niaki et al., 2017; Steen et al., 2018), while Kuo and Shih (2016) mention gender differences as a contributing factor, noting higher waste levels among females in university settings. Meal quality also plays a role, with Sundin et al. (2023) debunking the notion that popular dishes result in greater waste in a public catering setting. Special diets have been pinpointed as a significant source of waste in the same sector (Eriksson et al., 2017). Other studies have found that external food purchased by students, number of seats in a dining area, time allowed to eat and portion size are correlated with increased waste, often due to overproduction (Boschini et al., 2020; Lonska et al., 2022; Malefors et al., 2021b; Marlette et al., 2005; Steen et al., 2018; Zhang et al., 2024). Furthermore, type of kitchen (production or satellite) can significantly affect waste levels, with production kitchens being more efficient (Eriksson et al., 2017).

Previous studies of mitigation strategies for reducing food waste in the food service sector includes removal of trays, adjustments of the food service system and plate size reduction, but evidence of their effectiveness is not clear (Gao et al., 2021; Kallbekken and Sælen, 2013; Malefors et al., 2021a; Obersteiner et al., 2021; Qi et al., 2022; Richardson et al., 2021; Thiagarajah and Getty, 2013). Some studies suggest that setting goals on an organisational level is an important strategy for food waste reduction (Eriksson et al., 2023; Martin-Rios et al., 2018). In addition, Filimonau and Coteau (2019) demonstrated that kitchen manager training is crucial when it comes to the food waste issue, since kitchen managers oversee operational decisions that can either exacerbate or alleviate waste, depending on the presence of organisation policies that either hinder or support waste reduction efforts. One such example is how to organise and serve food, e.g. an “all-you-can-eat” format has been demonstrated to generate higher levels of waste (Chang, 2022; Eckert Matzembacher et al., 2020).

Even if all guests are subject to the same organisational factors, individual outcomes may differ significantly, indicating that not everyone faces the same issues. Malefors et al. (2024) illustrate this by showing that a minority of guests (20 %) account for a majority (60 %) of plate waste in school canteens. It has been suggested that extroverted individuals have greater potential to influence others in a food waste context, highlighting the importance of studying this aspect further and of determining how group dynamics influence food waste generation (Jamaludin et al., 2020; Persson Osowski, 2012). This suggests a need for tailored interventions targeting high-profile wasters, rather than applying general measures to all guests.

Effective food waste strategies must therefore be tailored to the unique operational context of each canteen. Policies that support food waste prevention can facilitate adoption of various measures, from education campaigns to sophisticated forecasting tools and plate waste tracking systems (Malefors et al., 2022b; Martin-Rios et al., 2018; Rodrigues et al., 2024). To be successful, these measures require fundamental elements such as clear waste reduction targets, knowledgeable staff, a streamlined menu and conversion of satellite kitchens into production facilities. The organisation also needs a clear understanding of the behaviours of guests, in order to make informed decisions on how to design food waste reduction interventions. Previous research on food waste in public catering is extensive but often based on small or single-case studies (Eriksson, 2025). To broaden this perspective, this study analyses food waste at three levels: the organisational level (policies and kitchen systems), the canteen level (student and school characteristics), and the individual level (behaviour and social factors).

To bridge this identified research gap, this study empirically evaluated the influence of organisational strategies and social factors on food waste mitigation. Specifically, it examined the efficacy of four main factors within organisations and their relationship to food waste: (i) having explicit food waste reduction targets, (ii) the share of staff with chef training, (iii) the share of guests that eat within

production kitchen facilities, and (iv) the share of guests that eat a special diet. All these factors are influenced or decided by the organisation within which canteens operate. In this study, the term organisation refers to the municipal public catering organisation that manages multiple production or satellite kitchens within a local authority. Each organisation thus represents a system-level unit that oversees several canteens and staff, sets policies, and allocates resources, rather than an individual business or kitchen. In order to identify factors generating food waste at school level, links between food waste and factors such as student age and gender and their parents' background were examined. Finally, to further understand the issue of food waste generation in the public catering sector, food waste generating factors at the individual level that could influence guest behaviour within canteens were examined, to better understand the characteristics of the individuals who waste most food. The ultimate goal was to obtain actionable insights that can aid in the pursuit of a more sustainable and responsible food service industry.

2. Material and methods

This study was conducted within the Swedish public catering sector, with a specific focus on school canteens. Although public catering in Sweden also includes preschools and elderly care facilities. The school segment was selected as the main focus, since it represents the majority of meals served within public catering and provides the most comprehensive and comparable food waste data across municipalities. Public catering facilities, for example in schools or hospitals, are typically part of a larger organisation with multiple levels of decision-making. They can serve various consumer groups and allow individuals to serve themselves from a buffet and make independent decisions regarding their consumption. Studying Swedish public catering organisations also represents a unique research opportunity since they have been active in quantifying food waste by direct observation for years, although they often focus on quantification for a couple of weeks per semester (Engström and Carlsson-Kanyama, 2004; Eriksson et al., 2018, 2020; Swedish Food Agency, 2021). The quantification data are publicly available for study, as they fall under the Swedish Public Access to Information and Secrecy Act (Swedish Parliament, 2009). The Swedish public catering sector is primarily operated by public catering organisations that are responsible for provision of food to preschool, schools and elderly care in Sweden's 290 municipalities (Swedish Food Agency, 2019a). The sector represents a substantial proportion of the country's meal landscape, since an estimated 50 % of all midday meals in Sweden are served within this sector (Delfi, 2015). The majority of meals are served in school canteens, to children aged 6–19 years, as part of a public scheme where school meals are provided to all students free of charge, funded by taxes (Swedish Parliament, 2010). Adding to the sector's commitment and transparency, the Swedish Food Agency has been collecting annual food waste data since 2019, contributing to the reporting obligations to the European Union (Swedish Food Agency, 2019a).

2.1. Area of study and description of multi-level data collection

This study examined food waste across three major levels and the relationship to various factors. The first level addressed was food waste and related factors at the national and public catering organisation level, the second was plate waste and factors at the school level and the third was characteristics of individuals who waste food, based on observations. To verify the observational findings, interviews were conducted with canteen staff.

2.1.1. Food waste at national level and organisational factors

The data on food waste quantities used for analysing organisational factors were collected through an annual survey conducted by the Swedish Food Agency (Swedish Food Agency, 2019a, 2021, 2023). This survey gathers information from municipalities and their public catering organisations, which include preschools, schools and elderly care facilities. Municipalities report the amount of food waste generated in these facilities, divided into kitchen waste, serving waste and plate waste for each type of operation. Each municipality aggregates and reports a single value for each type of operation (preschool, schools, elderly care facilities) within their public catering organisation. The values are based on the actual mass of discarded food, weighed according to a standard set by the Swedish Food Agency in 2019 (Swedish Food Agency, 2019b).

The reported food waste data are normalised by relating the values to the number of guests. Surveys were conducted in 2019, 2020 and 2021 with roughly 60–70 % of the 290 Swedish municipalities participating.

The Swedish Food Agency also maps various organisational factors in the Swedish public catering sector (Swedish Food Agency, 2022). The latest mapping was conducted in 2021, when data on the following factors related to food waste were collected.

- Whether an organisation has a goal for reducing food waste.
- The share of staff that have chef training.
- The share of guests eating in a production kitchen canteen.
- The share of guest eating a special diet.

These factors have only been mapped for one year, so we assumed that the answers provided in 2021 were also valid for the food waste data collected in 2019, 2020 and 2022. While this assumption introduces some uncertainty, these organisational characteristics (such as waste reduction goals, staff training levels and meal service arrangements) are relatively stable over time and not expected to have changed substantially between 2019 and 2022, despite the temporary operational adjustments during the Covid-19 period, where Swedish schools were held open (Malefors et al., 2021a). Total food waste per guest was calculated from the data provided by the municipalities, and their responses regarding organisational characteristics were combined into one dataset for analysis. Total food waste per guest in this case included only serving waste and plate waste, as kitchen waste was not reported by all responding

municipalities.

Since the food waste data were based on self-reported values from municipalities, a filter was used to remove responses from municipalities reporting total food waste of more than 150 g/guest, as such high levels are unlikely to be representative. Additionally, municipalities had to have reported food waste in the annual survey more than once. Applying these criteria removed 37 instances of food waste data, resulting in a total of 263 data points, spread across the three years and representing 111 municipalities, being retained for further analysis.

2.1.2. Drivers of food waste at school level

To examine food waste generating factors at school level, previously collected food waste quantification data were used (Malefors et al., 2019, 2022a). These data, which include the actual mass of discarded food weighed daily according to Swedish Food Agency standards, also provide information on the number of guests contributing to the food waste. A subset of the data from 2019, 2020 and 2021 was utilised, covering 88,873 daily observations from 93 municipalities and 1053 schools. This data subset was combined with official statistics from the Swedish Agency for Education, which annually surveys all schools in Sweden to determine number of enrolled students, percentage of girls, percentage of students with parents of foreign background and percentage of students' parents with higher education. All this information was merged into a single dataset for analysis. For these factors, plate waste per guest was used as the dependent variable.

The dataset was first filtered to remove questionable data, e.g. only days for which schools reported serving waste, plate waste and the number of guests were considered (Malefors et al., 2019). Additionally, any instances where plate waste exceeded 500 g/guest were removed. Applying this filter removed 15,347 data points. The remaining data were grouped per school canteen and average plate waste per guest and school was calculated. Only school canteens with more than 10 days of observations were included in the analysis, which resulted in observations from 693 schools across the years.

2.1.3. Food waste influencing factors and behaviour at individual level

To complement the national and school-level data, on-site observations of individuals who waste food were conducted in five schools (Schools 1–5) for three days each during spring 2024. These observations aimed to identify individual behaviours related to plate waste in the canteen environment and were conducted in schools equipped with a plate waste tracker, i.e. a device consisting of digital scales connected to a tablet computer running software that provides feedback on the amount of plate waste each person discards. Each time food is thrown into a dedicated bin, located near where the students return their dishes, the weight is displayed on the tablet (Malefors et al., 2024). Only guests who discarded more than 4 g of food waste were recorded, i.e. those who threw away no or very little food were excluded. The estimated age and sex of each individual were noted, along with observations on extroversion and group dynamics. These traits were chosen to examine the role of peer pressure and determine whether certain individuals act as leaders, influencing their food waste behaviour and that of others. Extroversion and group dynamics were assigned, when possible, based on the noticeable indicators outlined in Table 1.

During the observations, the observer sought to maintain a low profile and not interfere with the guests, while still having a clear view of the plate waste tracker. The observer aimed to minimise attention and maintain neutrality to avoid influencing student behaviour or making them feel judged. However, the students were inevitably curious, so questions were answered briefly to prevent potential biases without revealing the study's purpose.

A total of 1722 observations were made, with 461 observations in School 1, 427 in School 2, 422 in School 3, 224 in School 4 and 188 in School 5. Table 2 shows the distribution of plate waste observations across the different age groups.

Table 1

Overview of the parameters observed within the study, assigned values and indicators.

Parameter	Assigned values	Indicators
Plate waste	Plate waste/guest (g)	The amount of plate waste per person as displayed by the plate waste tracker (degree of precision: whole grams).
Age	6–8 9–10 11–12 13–14 15–16 16–17 17–18 18–19	Student age was approximated by the observer based on appearance, including height, body shape, facial features, voice and general body characteristics related to puberty. The estimates made were partly corroborated by a school year-specific lunch schedule provided by the head chefs at Schools 1 to 4. However, at School 5, different school years did not have a specified lunchtime.
Sex	“male” or “female”	Student sex was estimated subjectively by the observer based on societal norms and standards, considering factors such as facial and body features, haircut, clothing style and voice.
Extroversion	“low” or “high”	Low extroversion: Displaying body language such as lowered gaze, avoiding eye contact and hunched shoulders. Often hides behind the hood of a sweater and wears headphones. High extroversion: Speaking loudly and confidently, wearing eye-catching styles with bright colours or unconventional/extravagant designs, performing actions that attract attention and appearing to enjoy the attention. This trait was estimated by the observer.
Group dynamics	“yes” or “no”	Students were considered a “group” if they returned their plates together and their interactions indicated friendship, rather than just coincidentally returning plates at the same time. This was based on the observer's subjective opinion.

2.2. Analysis

Visualisation using boxplots and scatter plots with smooth lines fitted by Generalized Additive Models (GAM) (Hastie and Tibshirani, 1986; Wood, 2017) was carried out to illustrate relationships between food waste and identified aspects, i.e. organisational factors and total food waste, school factors and plate waste, and individual characteristics and plate waste generation. For some factors, correlation analysis was performed to evaluate the impact of that factor's influence on food waste levels.

2.2.1. Food waste at national level and organisational factors

To examine the impact of the factor “whether an organisation has a political goal to reduce food waste”, municipalities were grouped into those with a goal and those without in each year. A 95 % confidence interval for mean total food waste was then calculated for each group and year.

For the remaining factors, i.e. “share of staff with chef training”, “share of guests eating in a production kitchen canteen” and “share of guests eating a special diet”, total food waste for each municipality and year was averaged per organisation. The share of staff with chef training per municipality was reported in percentage ranges (e.g. 1–9 %, 10–19 %, etc.). The visualisations of the relationships between different factors and total food waste generation were complemented by correlation analysis to determine the strength of each factor's influence on food waste levels. Since the data for all factors were non-linear, Spearman's rank correlation was chosen as the most suitable method to calculate these correlations.

2.2.2. Plate waste at school level

To develop a relative measure for comparing children's age across schools and how this relates to plate waste, a “comparable age” metric was calculated for all schools, following Steen et al. (2018), but with an added constant to approximate student's actual age (Equation (1)).

$$\text{Comp age} = 7 + \frac{\sum_{i=1}^n y_i}{n} \quad (1)$$

Where y_i denotes the numeric value of each school year represented at a school (1 = year 1, 2 = year 2, ..., 12 = year 12), and n is the number of school years present. The addition of 7 reflects the typical starting age in Swedish schools.

Due to the non-linear nature of the data and the presence of many ties, Kendall's rank correlation was chosen as the most suitable method for calculating correlation coefficients. Data from 719 schools were used for this analysis.

Spearman's rank correlation was chosen as the most suitable method to calculate correlation coefficients for how sex and age influence plate waste, as well as for the factors regarding the share of parents with higher education and the share of parents with a foreign background.

2.2.3. Individual characteristics and plate waste

All plate waste observations and factors were examined as a group. The individual level factors (age, sex, extroversion, group dynamics) were analysed against average plate waste per individual using 95 % confidence intervals. A linear model incorporating age, sex and their interaction was used to determine adjusted R^2 , providing a measure of how well the model explained the variation in the outcome data.

2.3. Verification of reported food waste quantification data and interviews

To verify the accuracy of the values reported by municipalities in the annual survey conducted by the Swedish Food Agency, the survey data were compared against previously collected food waste quantification data at school level from the same municipalities. This comparison aimed to assess how well public catering organisations compile their own quantification data.

The process involved grouping all school food waste data by municipality and year, and then calculating descriptive statistics. These statistics were compared against the values reported by the municipalities each year. Reported values from public catering organisations were considered accurate if they were within ± 10 % of the calculated percentage difference of the mean values from the

Table 2

Distribution of plate waste observations across different estimated age groups, segmented into number of female and male wasters within each specified age range, providing an overview of the demographic spread in the observations.

Age group	Female	Male
6–8	206	203
9–10	119	126
11–12	175	237
13–14	166	113
15–16	109	80
16–17	46	42
18–19	19	81

quantification data. Additionally, 95 % confidence intervals were computed for the quantification data, and it was noted whether the values reported by the public catering organisations fell within these intervals. Data from 57 municipalities were matched, i.e. public catering organisations had reported values to the Swedish Food Agency and we also had raw food waste quantification data from schools within the same organisation.

Collecting data on human behaviour and dynamics in specific environments, such as a school canteen, is challenging. While observations provide valuable insights, factors such as student background, parents' education level and dietary preferences are not easily observable. Interviews can offer in-depth information from those familiar with the environment and the individuals (Kanazawa, 2017). For the purposes of this study, canteen staff were identified as key informants due to their understanding of canteen dynamics and their guests. Interviews were conducted with staff from the same schools (Schools 1–5) where observations took place and the responses were used to verify the data collected in observations. Canteen staff members selected interviewees (Respondents 1–5) based on their familiarity with students. All interviews followed a semi-structured guide focused on three categories: student characteristics, behavioural factors and food-related factors. Interviews began with general questions about the respondent's role and the plate waste situation, followed by category-specific questions. Open questions allowed respondents to freely share insights, followed by specific queries. As summarised by Kallio et al. (2016), this approach allows for spontaneous follow-up questions and gives respondents the freedom to elaborate on their answers, ensuring consistency in structure and comparability of the interviews while allowing unexpected topics to arise.

3. Results

The results are presented below in four separate sections. Section 3.1 covers the organisational/municipality level, section 3.2 the school level and section 3.3 the individual level. Section 3.4 covers verification and data and insights gained from the interviews with

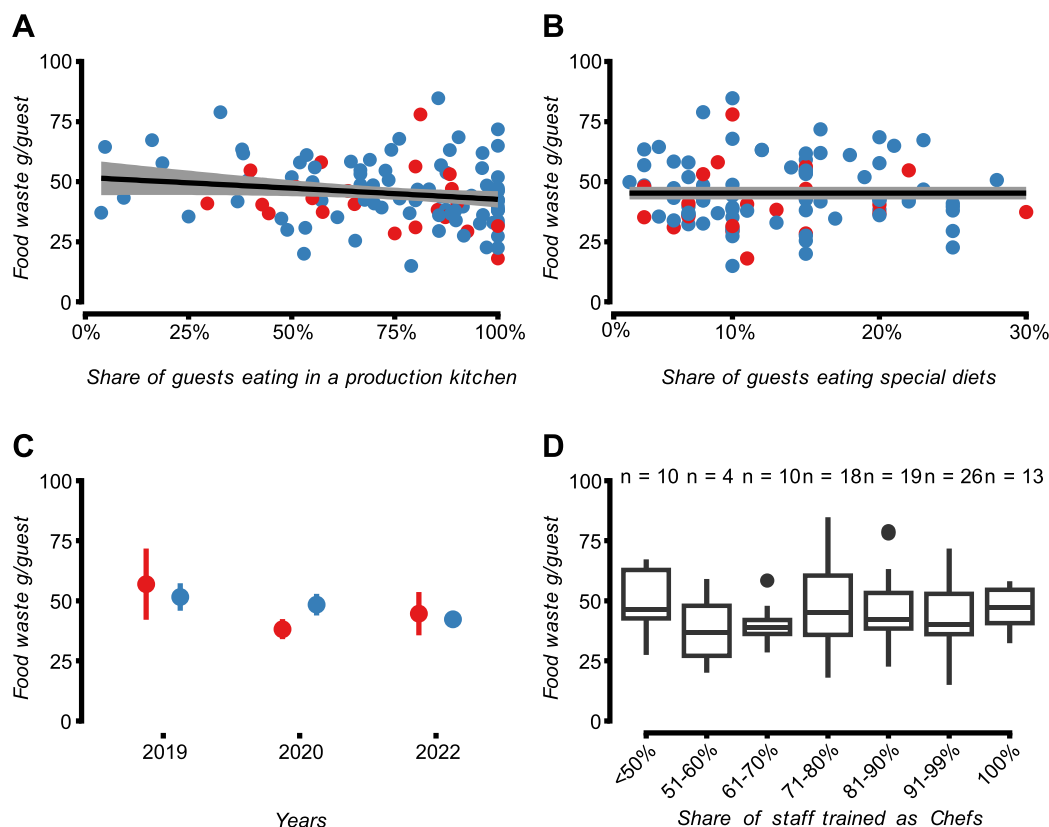


Fig. 1. Scatter plots showing (A) the percentage of guests eating in a production kitchen canteen and (B) the percentage of guests eating a special diet, as reported per municipality, compared with reported levels of food waste (g/guest). Organisations with a food waste reduction goal are marked with (●), those without with (●). Trendlines (—) are based on Generalized Additive Models (GAM), representing the mean, with the shaded area indicating the 95 % confidence interval. (C) Comparison of organisations with a food waste reduction goal and those without such a goal, over the available years. Points indicate average food waste (g/guest) with 95 % confidence interval. (D) Boxplot showing the percentage of staff with chef training in responding municipalities and the corresponding level of food waste (g/guest). Centre lines indicate the median, box limits indicate the 25th and 75th percentiles as determined by R software, whiskers indicate 1.5 times the interquartile range from the 25th and 75th percentiles, and outliers are represented by dots. Sample size for each group is shown above the boxplot.

the staff.

3.1. Organisational level

The results obtained at organisational level indicated a weak negative correlation ($\rho = -0.23$) between the prevalence of guests eating in production kitchen canteens and lower levels of food waste. This suggests that municipalities with more guests eating in production kitchen canteens tend to have less food waste (Fig. 1A). The results also indicated that municipalities with a goal to reduce food waste had similar levels of food waste to those without such a goal. Municipalities with a waste reduction goal reported 47 g of food waste per guest (95 % CI: 44–50 g), while those without a goal reported 45 g/guest (95 % CI: 40–50 g). However, there was greater variation in reported food waste levels among municipalities without a goal than among those with a waste reduction goal. Over time (between 2019 and 2021), both groups reported a decrease in their level of food waste (Fig. 1C). On examining the impact of staff training level on food waste, no clear trend is observed across the different training levels. The distribution of food waste levels for each group and their sample size are shown in Fig. 1D. The results indicated no correlation ($\rho = 0.04$), between the number of guests requiring a special diet and the level of food waste (Fig. 1B).

3.2. School level

The results at school level showed that older students tended to generate more plate waste, with Kendall's $\tau = 0.34$, indicating a moderate correlation. Specifically, students around 18 years old wasted about 36 g/guest on average, which was twice the amount generated by 10-year-old children, who wasted around 18 g/guest (Fig. 2A).

Regarding the role of gender in plate waste generation, the proportion of girls in school years 1–12 showed no correlation with plate waste ($\rho = -0.08$). There was no evidence that schools with older students or with a higher proportion of girls wasted more or less food

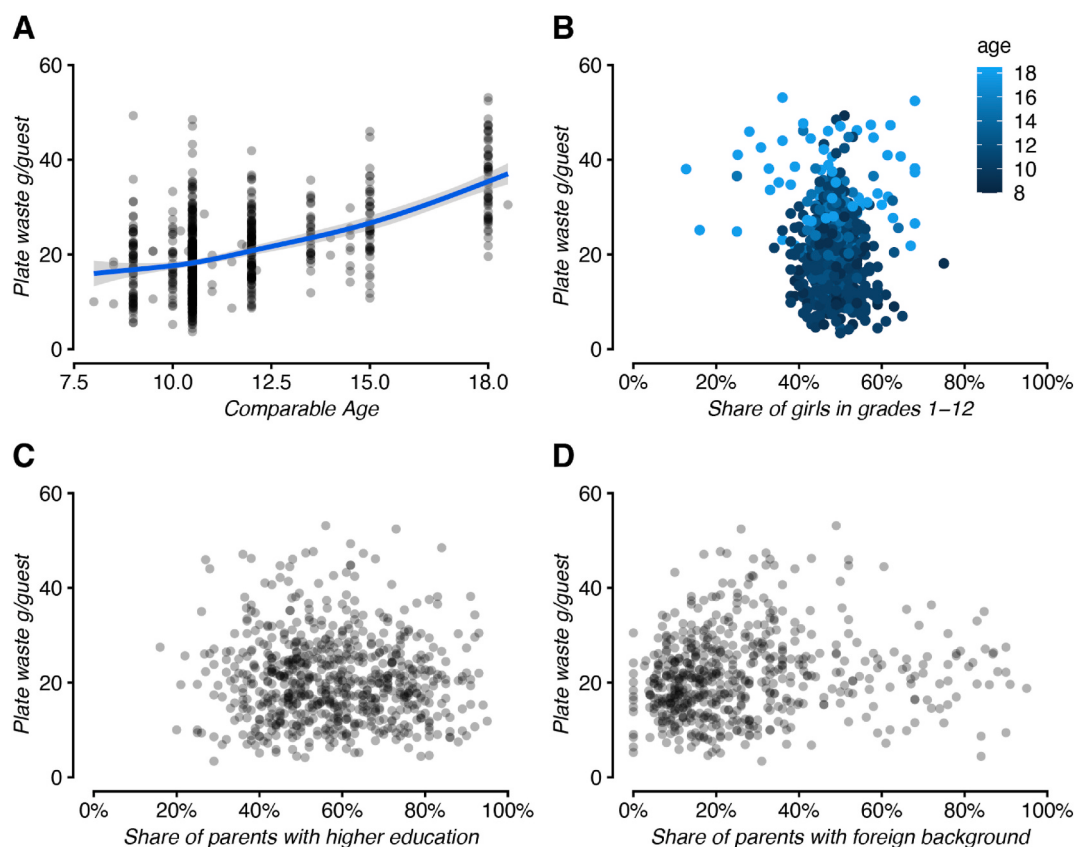


Fig. 2. (A) Scatter plot showing the relationship between comparable age (sum of all school years represented at a school, divided by the range of years) and plate waste (g/guest). The blue trendline is based on a Generalized Additive Model (GAM), with the shaded area representing the 95 % confidence interval. (B) Scatter plot illustrating the relationship between the proportion of girls in school years 1–12 (%) and plate waste (g/guest). The colour gradient represents age, with lighter shades indicating older students. (C) Scatter plot showing the relationship between percentage of parents with higher education and plate waste (g/guest). (D) Scatter plot showing the relationship between percentage of parents with a foreign background and plate waste (g/guest). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

than schools with younger students or with a higher proportion of boys (Fig. 2B).

The share of students whose parents had higher education showed no correlation with plate waste, with Spearman's ρ of -0.03 (Fig. 2C). The share of students whose parents had a foreign background also showed no correlation with plate waste ($\rho = 0.18$) (Fig. 2D).

3.3. Individual level

The observations at individual level revealed a similar trend as seen at school level, i.e. older guests tended to generate more plate waste than younger guests (Fig. 3). On combining the data for sex and age, males generated more plate waste on average across all the age groups except one (males aged 6–8 years). The linear model, which included sex, age and their interactions, explained only a small proportion of the variance in plate waste (adjusted $R^2 = 0.03$). This suggests that other factors not included in the model also play a significant role and that there is substantial variation in the data.

As shown in Fig. 4A, there was noticeable variation in plate waste based on the level of observed extroversion. Individuals classified as highly extroverted generated the most plate waste, with an average of 67 (95 % CI: 56–78) g/waster. Those with low extroversion levels generate 53 (95 % CI: 42–64) g/waster. Individuals who did not display any clear traits of either high or low extroversion generated plate waste averaging 53 (95 % CI: 50–56) g/waster (Fig. 4).

Students who arrived in groups to throw away food tended to waste slightly more food, with an average of around 58 (95 % CI: 51–65) g/waster, compared with 54 (95 % CI: 51–57) g/waster for those who were not in groups (Fig. 4B). However, based on the confidence interval for both extroversion and group dynamics (Fig. 4), the differences between the groups were not statistically significant.

3.4. Verification of food waste data and of observations

On evaluating how accurately the values reported by public catering organisations matched the actual food waste quantification data, we found that 26 out of 57 organisations reported values within ± 10 % of the quantified data, while 23 organisations reported values within the 95 % confidence interval of the quantified data. Notably, a majority (35/57) of the organisations reported values lower than the calculated food waste levels based on the quantification data. The results are illustrated in Fig. 5.

To verify the on-site observations, we conducted interviews with the staff to determine their perception of factors driving plate waste. Respondent 1 observed that older students tend to care less about food waste, and thus waste more. Respondent 2 noted that students up to school year 6 are supervised during lunch and may follow dietary restrictions set by parents, leading to waste if they prefer other foods. According to Respondent 2, age-related waste differences are also linked to varying food preferences and stronger group dynamics starting from year 6. Respondent 3 mentioned that younger students like following rules and being praised, while teenagers are less concerned about food waste and forget efforts to reduce it. Respondent 4 perceived that year 9 students waste the most and emphasised the importance of early awareness efforts. Respondent 5 also noted an increase in waste from year 9 onwards and mentioned that rewards for low waste are less effective for older students. This aligns with Respondent 1's observation that such interventions are more successful with younger students in their school.

When it comes to sex differences, Respondent 1 said it was challenging to determine whether boys or girls waste more food.

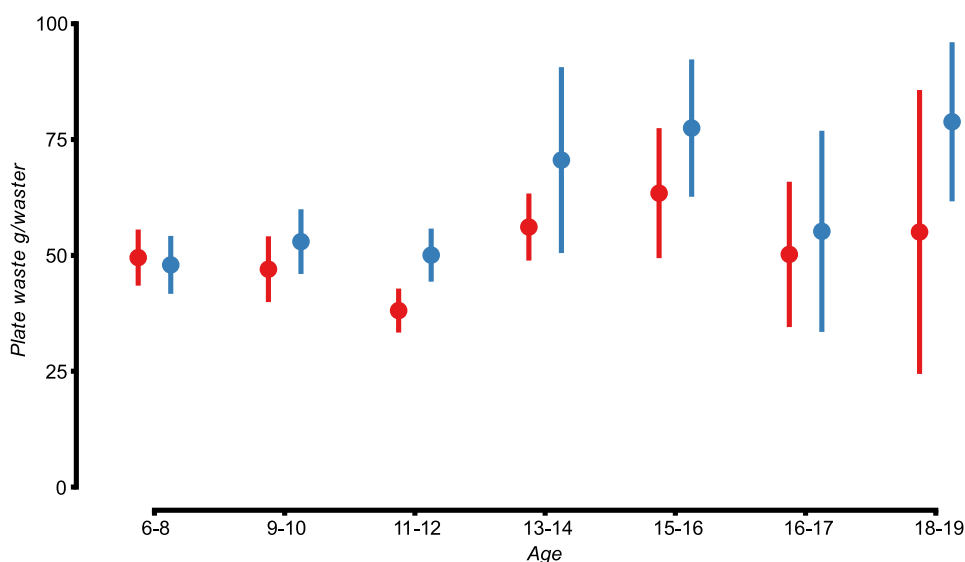


Fig. 3. Plate waste (g/waster) by age and sex. Within each age group, males (●) generally wasted more food than females (●), with the amount of waste increasing with age for both sexes. Bars represent 95 % confidence interval.

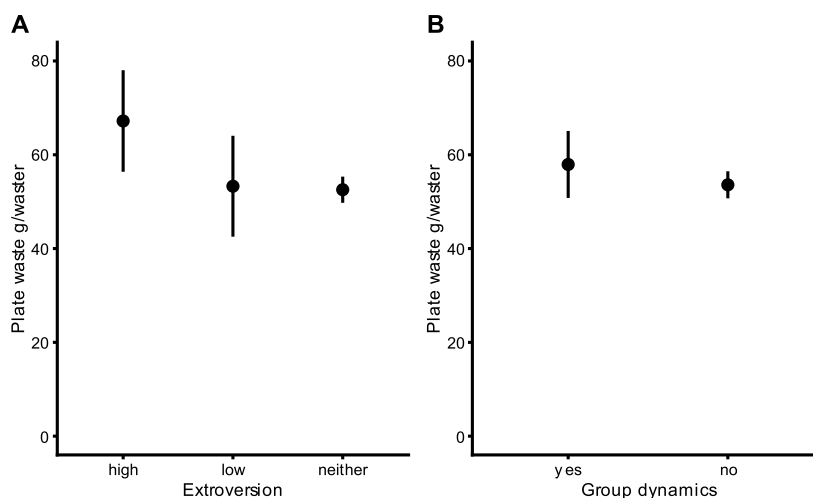


Fig. 4. (A) Plate waste (g/waster) by level of extroversion. Guests with high extroversion level generated the most plate waste, followed by those with low extroversion, and finally those who displayed neither trait. (B) Plate waste (g/waster) based on whether students cleared waste from their plates in groups or not. Guests who were observed arriving in groups generated slightly more plate waste than those who were not in groups. Each point represents average plate waste per waster, with error bars indicating the 95 % confidence interval.

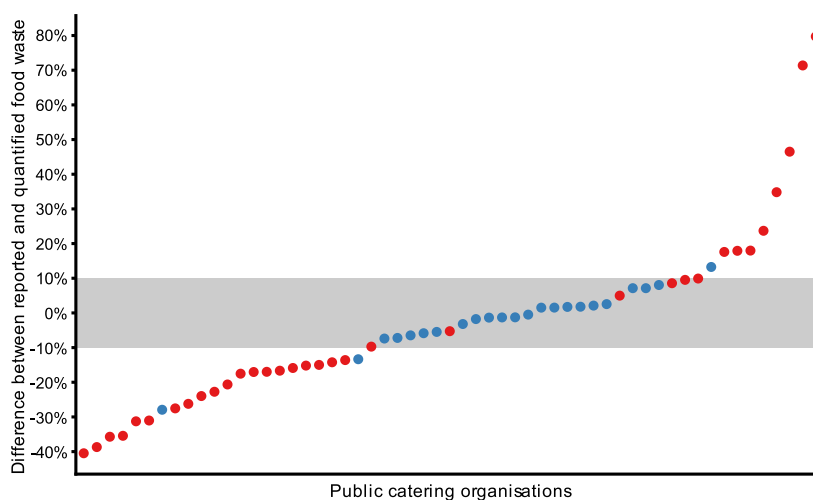


Fig. 5. Difference between reported and quantified food waste at public catering organisations. Each dot represents data from a different public catering organisation, with the y-axis showing the percentage difference between reported and quantified food waste. The shaded grey area represents the $\pm 10\%$ range, within which the reported values can be considered accurate. Blue dots (●) indicate organisations with reported values within the 95 % confidence interval, while red dots (●) indicate organisations outside this range. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Respondent 2 believed there is no difference between boys and girls in terms of average food waste. Respondent 3 observed that boys tend to take more food than girls, leading to more waste when they realise they have taken too much. They also noted that boys are more willing to try new foods, whereas girls are pickier and often do not try the new food at all, resulting in less waste. Respondent 4 believed that boys waste more food, while Respondent 5 had the opposite impression.

According to Respondents 1 and 3, there is no significant correlation between students' backgrounds and plate waste at Schools 1 and 3. Respondent 2 noted that at School 2, the younger students, many of whom have lived in Sweden for most of their lives, are accustomed to Swedish cuisine, so their background has little impact on waste. However, students who must eat the vegetarian option because the meat dish is not in accordance to their religious views tend to waste the vegetarian dish if they prefer meat.

Respondent 4, from a school with older students (school years 6–9), pointed out that newer immigrants might not recognise regional vegetables and need encouragement to try them, but that waste primarily depends on the food's general popularity rather than the student's background. Respondent 5 agreed that background does not have a strong effect, but noted that male students with a

foreign background are more likely to try new foods and waste them if they do not like them, then return to the buffet for something else.

All respondents reported that they lack specific knowledge about the education backgrounds of students' parents. However, Respondent 2 shared insights into the financial situation of families, which might correlate with education levels. They noted that students from families struggling to afford enough food tend to eat more at school and waste less. Respondent 4 confirmed this observation, adding that parents with higher education seem more concerned about the environment and teach their children not to waste food.

Respondent 1 noted that some students eat calmly while others hurry to play, with the latter sometimes wasting food, but did not see a clear link to extroversion. Respondent 2 observed that year 6 students consider it "cool" to skip the hot meal and eat only crispbread, but found no connection to extroversion. Respondent 3 believed that extroverted students are less affected by peer pressure, while introverted students, especially those eating alone, tend to eat up. This suggests that extroverts may waste less due to social influences, while introverts waste less when alone. Respondents 4 and 5 mentioned group "leaders", often extroverted, who influence others' eating habits but do not necessarily waste more themselves. Respondent 5 agreed with Respondent 3 that timid students who eat alone waste less.

Similarly to "extroversion", it was noted during observations that students' urge to play can lead to food waste and that students influence each other, sometimes positively by criticising waste. This positive impact is more common among younger students (below year 6), while older students often joke about waste. Respondent 2 claimed that peer pressure to fit in or avoid judgment leads students to waste food or eat secretly. They reported that strong individuals can influence an entire class, especially from year 6 onward. Respondents 3, 4 and 5 confirmed that peer pressure can prompt students to leave the canteen before finishing their meals, resulting in waste. Respondent 5 noted that peer pressure is strongest among girls in years 10 and 11, but they act in a more mature way in year 12.

4. Discussion

The factors identified as contributing to increased food waste in school canteens were primarily student age and kitchen type (production or satellite kitchen). These findings need to be seen in the context of the Swedish school meal system, where all meals are tax-funded and mostly organised through municipalities. Whether kitchens are production or satellite units strongly affects flexibility in managing food waste, while the free provision of meals means that student behaviour becomes a major driver of plate waste. In municipalities with more guests eating in production kitchen canteens, food waste is lower (Spearman's $\rho = -0.23$), which is logical since a production kitchen has much greater scope to adjust production level and re-use leftovers, thereby reducing food waste. Older children tend to waste more food (Kendall's $\tau = 0.34$), with students around 18 years old wasting about 36 g/guest on average, which is twice the amount generated by 10-year-old children. Children serve themselves from a buffet and actual portion size might therefore vary between different individuals. Evaluation of individual factors revealed that older male students generally tend to throw away more food than female students, across almost all age categories. Older male students who exhibit extroversion traits could be a target group for future interventions, as this is a relatively small group in comparison with all students in a school. The other main factor, kitchen type, is difficult to address in the short-term, as buildings may need to be reconstructed or re-equipped to be used as production kitchens. Designing food waste interventions to target older male students in particular might be a much simpler solution to reduce food waste generation. This is supported by findings by Malefors et al. (2024) that food waste generation is concentrated to a small group of students.

Previous research has identified that females generally waste more food than males (Collison and Colwill, 1987; Kuo and Shih, 2016; Painter et al., 2016). However, most of those studies were conducted in a university canteen environment, with older students than in the present study (where guest age ranged from 7 to 19 years). Age has been highlighted previously as a factor influencing food waste levels, with older students tending to waste more (Byker et al., 2014; Eriksson et al., 2017; Steen et al., 2018), a finding supported by the results in this study.

In contrast to previous studies (Eriksson et al., 2017, 2023; Panizza et al., 2016), we found that setting waste reduction goals, training staff, the background of students' parents and the number of students eating a special diet did not significantly affect the level of food waste. However, certain factors combined may contribute to increased food waste. For example, having a large proportion of satellite kitchens within an organisation together with a high proportion of students requiring a special diet might increase food waste. To minimise the risk, it is advisable to design a regular menu into which special diet options are integrated, in order to reduce the number of alternative dishes while increasing the volume of each dish. For example, Eriksson et al. (2016) found that when a municipality reduced the number of dishes on their menu from three to two, this resulted in a 27 % decrease in food waste. In addition to setting goals, the goals also need to be communicated, monitored and acted upon, actions which were not investigated in this study.

Based on our findings, setting goals alone is not sufficient to reduce food waste. However, organisational goals may need time to become fully integrated within every branch of the organisation or by each person, due to the inherent inertia in establishing new routines and change behaviour (Amicarelli et al., 2022; Persson Osowski et al., 2022; Principato et al., 2020). Additionally, our analysis included only organisations that set goals on an organisational level, and it is of course possible that organisations without goals still include individual school canteens working effectively with food waste reduction goals. Another aspect is that our material only included organisations which could provide data that met strict criteria, possibly skewing the results towards those most invested in food waste issues and with well-developed quantification systems and reduction ambitions. Most organisations included in our study already had well-trained staff, which might explain the lack of differences in food waste generation between staff training levels. There were only a few data points where fewer than half of all staff had no chef training, so most of our participating organisations may have had a sufficient level of staff training, reducing the variation between kitchens.

Like all other food waste studies, this study is limited by the fact that we could not isolate individual factors, as they are all present simultaneously. Additionally, we may have observed only the best canteens or organisations, meaning that we lacked a representative sample, although despite this we observed significant variations within the organisations, schools and individuals studied. There are also limitations relating to the data, e.g. data collected at the organisational and school level were obtained through surveys, which can introduce reporting errors. However, verification showed that approximately half of the participating organisations report food waste data accurately in relation to the underlying data.

There are also obvious limitations based on the data at individual level, which were based on the observers' personal perceptions and collected at only five schools. Participant observation involves immersing the observed in the field of study, to gain insights into the lived reality and social dynamics (Logan et al., 2023). In the present study, the observer sat near the plate waste tracker. Although efforts were made to remain low-profile, the observer needed a clear view of the tracker to record plate waste accurately, making their presence noticeable. The observer aimed to minimise attention and maintain neutrality, to avoid influencing student behaviour or making them feel judged. However, curiosity among students and staff was inevitable, and questions were answered briefly to prevent potential bias by not detailing the purpose of the study. In terms of the definitions in Roller and Lavrakas (2015), this aligns more with "on-site non-participation observation", as the observer did not engage with students over lunch. Nevertheless, slight traits of "passive participant" were present due to unavoidable verbal exchanges. Kanazawa (2017) describes this as "observer as participant", where subjects are aware of the research, maintaining high objectivity, but potentially lacking some insight compared with more active participation.

Our findings suggest that extroversion tends to influence plate waste generation, with highly extroverted individuals in our study contributing on average 67 g/waster (95 % CI: 56–78 g) compared with 53 g/waster (95 % CI: 42–65 g) for introverted individuals. Social dynamics, and especially disposing of plate waste in groups, may also play a role, generating 58 g/waster (95 % CI: 51–65 g), compared with 54 g/waster (95 % CI: 51–57 g) for those not operating in groups. These insights highlight the importance of considering personality traits and social behaviours when developing strategies to reduce food waste. We attempted to verify the observations through staff interviews, but staff opinions may not always align with empirical data since e.g. Sundin et al. (2023) found discrepancies between staff perception and actual food waste, especially regarding popular or unpopular meals.

Another key consideration was that we only focused on guests who discarded food, to understand the behaviour of those who waste. While we found that older males tend to contribute more food waste, this does not mean that teenage boys were absent from the group of non-wasters. Another notable finding was that fewer older females were observed throwing away food compared with older males, highlighting the need for further observations to fully understand the situation. A comprehensive study observing all children through the entire meal in the dining environment might reveal more complex patterns (Wiggins et al., 2024).

No previous study has assessed the effect of extroversion on the amount of plate waste. However, Jamaludin et al. (2020) found that extroverted individuals are more likely to take on a "leader" role and suggest that students with this trait may be more eager to discover solutions to problems, meaning that they have greater potential to influence others in a food waste context. This frames the "leader" character as a role model, but interviews at the local level present a less favourable picture, showing e.g. that leaders can intimidate other students and that their opinions on food quality often override individual preferences (Persson Osowski, 2012). This can lead to more plate waste from less extroverted students who are too ashamed to admit they like the food and to more serving waste if large groups refuse the main dish because one influential student does not like it (Persson Osowski, 2012).

Some factors influencing food waste do not necessarily translate into actionable measures that organisational or individuals can direct address. For example, aspects such as gender or age cannot easily be acted upon but rather require organisations or kitchens to find ways to account for and adapt these factors. This study shows how food waste relates to certain factors, but we cannot claim any causal relationship. A factor can co-vary with food waste without being the actual cause. Still, using objective data from weighing food waste, instead of relying on interviews, surveys, or other subjective sources gives a solid base for future research. We also report negative results, i.e. factors that do not correlate with food waste, which is rarely highlighted since most studies focus on positive findings. In order to form a policy recommendation having food waste reduction goals and well-trained staff are essential in addressing food waste, as is performing food waste quantification to track progress. However, our findings show that these factors alone are insufficient to reduce food waste. Organisations must act on quantification results and design interventions targeting the actual causes of food waste. Our results suggest that future interventions in the public catering sector should focus on the relatively small group of teenage males, to change their behaviour. Conventional information campaigns with factual messages about food waste and sustainability might not be enough to reach this group of older students, so instead we recommend targeted interventions and efforts to convert potentially negative peer pressure to positive pressure. Policymakers might find it difficult to intervene at this very local level, where local role models among the canteen staff, school leaders and teachers can play an important role and should be supported to do so. At a higher policy level, utilising production kitchens to a greater extent is a more pressing matter to reduce a major risk factor in food waste generation. Food waste varies greatly between individuals and situations, so instead of applying the same measures to everyone, we need to focus on the people and processes where the potential for reduction is actually highest. Taken together, our results show that food waste in Swedish schools is shaped by both system-level organisation and student behaviour. This helps explain why effective interventions need to target not only organisational and kitchen structures but also social dynamics among students.

5. Conclusions

This study showed that food waste generation in Swedish school canteens is mainly driven by student age and kitchen type (production or satellite kitchen). In fact, canteens with older students may waste twice as much as those with younger students. Other factors examined, such as whether the organisation has a food waste reduction goal, number of guests eating a special diet and parents'

background, were found to have weak correlations with food waste generation, although they might be important in combination (not studied here). On a personal level, we found that extroverted persons tend to generate more food waste than other students and that operating in a group tends to increase waste. We also found that older male students on average waste more than other students. Therefore, we recommend that future waste reduction efforts target the group-based social context or older male students, in order to intervene at the point of the system where food waste reduction has the highest potential.

CRediT authorship contribution statement

Christopher Malefors: Writing – review & editing, Writing – original draft, Visualization, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Theresa Gerstbrein:** Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Claudia von Brömssen:** Writing – review & editing, Formal analysis. **Niina Sundin:** Writing – review & editing. **Ylva Ran:** Writing – review & editing. **Fiona Lambe:** Writing – review & editing. **Mattias Eriksson:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The authors Christopher Malefors and Mattias Eriksson have developed the plate waste trackers used for data collection for parts of the study and own the rights to this tool through the company Matomatic AB. There is a potential conflict of interest as the company have a financial interest in the innovation.

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Data availability

Data will be made available on request.

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