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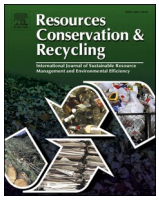

Full length article

# Testing interventions to reduce food waste in school catering

Christopher Malefors *, Niina Sundin, Malou Tromp, Mattias Eriksson

*Department of Energy and Technology, Swedish University of Agricultural Sciences, Box 7032, Uppsala SE- Uppsala, 75007, Sweden*

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ABSTRACT

Food waste is a problem that needs to be addressed to achieve sustainable development. There is a need for interventions that can reduce food waste, including in organisations already aware of the food waste problem. Swedish school canteens have experience of food waste reduction, but need tools to achieve further reductions. This study tested four interventions (tasting spoons, awareness campaign, a plate waste tracker and a guest forecasting tool) designed to reduce food waste in school canteens. Each intervention was introduced in two school canteens, while seven school canteens acted as a reference group. The interventions were compared with baseline food waste before the intervention and with the reference group. All interventions reduced total food waste (by 6 to 44 g/guest) compared with the baseline, but the reference group also reduced its food waste. The awareness campaign reduced plate waste most, by 13 g per portion, which was 6 g/portion more than the plate waste reduction in the reference group. The forecasting and plate waste tracker interventions reduced serving waste most, by 34 and 38 g/portion, compared with 11 g/portion in the reference group. Some interventions also had an effect on waste fractions they were not designed to target, affecting the total waste by shifting the waste. Interventions should always be seen in a context and be implemented in combinations that increase overall sustainability. Thus forecasting is an effective way to reduce serving waste, plate waste tracker and awareness campaign are effective tools to reduce plate waste in school canteens.

## 1. Introduction

There is a global problem with food waste in the food service sector, with some studies claiming that approximately 20% of all food served is wasted (e.g. Engström and Carlsson-Kanyama 2004; Katajajuuri et al. 2014; Eriksson, Persson Osowski, Malefors, Björkman, and Eriksson, 2017; Malefors, 2021; Malefors et al., 2019; Silvennoinen, Heikkilä, Katajajuuri, and Reinikainen, 2015). For school meals, which are part of the food service sector, studies have found that food waste levels ranging from 33 to 160 g/guest are not uncommon (Boschini, Falasconi, Cicatiello, and Franco, 2020; Eriksson et al., 2017). Food waste of this magnitude raises a series of issues. For example, it compromises public health regarding goals set for school meal schemes and jeopardises the nutritional needs of school children (Cohen, Richardson, Austin, Economos, and Rimm, 2013; Smith and Cunningham-Sabo 2014). Food waste is also associated with major waste of resources, with high cost and environmental implications (Cohen et al., 2013; Falasconi, Vittuari, Politano, and Segrè, 2015; García-Herrero, De Menna, and Vittuari, 2019; Scholz, Eriksson, and Strid, 2015). Ultimately, it can lead to transgression of planetary boundaries (Campbell et al., 2017; Springmann et al., 2018). Efforts are underway to curb the food waste problem. One such global initiative is the United Nations framework for sustainable development (United Nations, 2015), which includes reduction of food waste under target 12.3 of the Sustainable Development Goals: "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chain". However, some argue that this level of ambition is not high enough and that further reductions are necessary to create a food system that can meet the target by 2050 (Beretta and Hellweg 2019; Springmann et al., 2018).

In a Swedish perspective, the food service sector is an important actor in the food chain, since it comprises a large number of public catering establishments, organised through municipalities and regions, providing food to preschools, schools, hospitals and elderly care homes. It has been estimated that half of all lunches in Sweden are served within this sector (Delfi, 2015). This is mostly because school children aged 6 to 16 receive a warm cooked meal every school day, free of charge, regardless of parental income (Swedish Parliament, 2010). These school meals are regulated by the Education Act, which only applies to school children aged up to 16 years, but in practice many young people in

* Corresponding author.
*E-mail address:* christopher.malefors@slu.se (C. Malefors).

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upper secondary school (aged 17–19 years) are also encompassed by the scheme. The Education Act states that school meals must be funded by tax revenue and that they must be nutritious (Swedish Parliament, 2010). Balanced nutrition that meets the physiological needs of children is essential for their growth and development (Nordic Council of Ministers, 2008). Nutritious school meals can also have a positive influence on cognitive function and thus the academic performance of school children (Hayes, Contento, and Weekly, 2018; Lennernäs, 2011). School meals are therefore planned based on the official nutrition recommendations and must supply approximately 30% of the daily nutrient and energy needs of children (Swedish National Food Agency, 2019b). However, for school meals to fulfil their nutritional goal, it is critical that the dishes served are consumed as planned, generating as little waste as possible.

Extensive food waste quantification has emerged as a first step to identify existing issues in public catering establishments (Eriksson, Lindgren, and Persson Osowski, 2018a). However, quantifying food waste is seldom enough, but is merely a tool necessary for initial identification of the problem and for subsequent checks on whether interventions made have had the desired effect (Eriksson et al., 2019). An important next step is to identify interventions that reduce food waste most efficiently, which canteens should prioritise. There is potential to reduce negative environmental impacts from wasteful behaviour and to ensure that children's energy and nutrient needs are met, for their healthy development. Some previous studies investigating the effect of single interventions mainly targeting plate waste, such as information campaigns (with written messages such as posters and table talkers), have reported a range of results, from no food waste reduction to a 28% reduction (Visschers, Gundlach, and Beretta, 2020; Whitehair, Shanklin, and Brannon, 2013). Other interventions, including redesigning schedules so that lunch is in relation to recess (Getlinger, Laughlin, Bell, Akre, and Arjmandi, 1996), introducing tasting spoons (Tocco Cardwell, Cummings, Kraft, and Berkenkamp, 2019) and nudging initiatives (Kallbekken and Sælen 2013; Thiagarajah and Getty 2013), have been found to reduce food waste by up to 20%. Forecasting has also been identified as a potential solution to reduce food waste and especially serving waste, in theory by 20–40% (Malefors, Strid, Hansson, and Eriksson, 2021b; Ryu and Sanchez 2003; Yurtsever and Tecim 2020), although few studies have examined how well actually forecasting works in terms of food waste reduction. The British organisation (2011) made three interventions (improving familiarity and appreciation of school meals, improving the dining experience, children ordering their meals in advance) and could show a 4% waste reduction, but the reduction was not statistically significant (WRAP, 2011). To conduct intervention studies, food waste quantification is required. It can therefore be argued that quantification itself is an intervention that affects the level of food waste, by raising awareness (Eriksson et al., 2019; Pancino, Cicatiello, Falasconi, and Boschini, 2021).

No previous study has investigated the food waste-reducing effects of interventions in an organisation that has actively quantified and worked with food waste for several years, and no study has assessed interventions targeting both plate waste and serving waste. Therefore the present study examined the effects of four interventions (all based on best available technology) on food waste levels in a Swedish public catering organisation that has actively quantified its amount of food waste since 2014. The interventions tested were: i) an information campaign directed at school children with the aim of reducing plate waste; ii) providing tasting spoons in canteens so that school children could taste dishes before serving themselves, with the ambition of lowering plate waste; iii) a plate waste tracker that communicated different educational messages on the impact of food waste to school children and gave them feedback on how much they wasted per portion; and iv) guest attendance forecasting, so that canteens could gain a better understanding of future demand and adjust their production accordingly.

The ability of these four interventions to reduce food waste in school canteens was tested both in relation to the baseline prior to implementation and in relation to a reference group. The objective was to identify interventions that could be scaled up so that school canteens can achieve the larger-scale reductions in food waste necessary for a sustainable food system.

## 2. Material and methods

The study comprised three main steps (Fig. 1): 1) food waste quantification to establish a baseline in participating school canteens; 2) design and implementation of interventions to reduce food waste; and 3) post food waste quantification to determine and evaluate the effect of the interventions.

### 2.1. Description of data collection and study material

Collection of data took place in a public catering organisation that provides food to preschools, schools and care homes in a Swedish municipality. The organisation operates a total of 30 kitchen units, half of which serve meals to school children aged 6–19 years. The majority of meals that the organisation serves are within the school segment, as schools are normally larger than preschools and care homes. The organisation has worked actively with the question of food waste and has regularly quantified its levels of food waste since 2014.

The pre-intervention quantification of food waste phase took place between 2014 and spring 2020 in the 15 school canteens, to establish a baseline level of food waste. All data were collected through self-monitoring by the kitchen staff, who weighed food waste as part of a daily routine during the quantification periods. The quantification periods varied in duration, but aimed to cover one period in the middle of the spring semester and one period in the middle of the autumn semester, when the canteens had full activity. Thirteen of the canteens serve meals to children aged 6–16 years and the remaining two school canteens serve children aged 17–19. All participating canteens quantified food waste by weighing the mass of waste (in kg with two decimals) using kitchen scales and reporting the information in a standardised format, as described by Eriksson et al. (2018b)) and Malefors et al. (2019). The waste processes recorded were kitchen waste (waste from goods delivered to the kitchen, but never stored or used or waste from preparation and/or trimming of food or waste from food produced which did not leave the kitchen for consumption and was not saved for another meal), serving waste (food served that did not reach the plates of the guests) and plate waste (waste from the plates of the guests, may contain napkins and/or inedible parts) for lunch meals served within the public catering organisation. The numbers of guests per meal and canteen were also recorded, to calculate the relative indicator 'waste per portion'. The number of guests was estimated by counting the number of used plates after the meal serving. The amount of food served was also recorded for some canteens during parts of the quantification period.

To have a robust evaluation procedure, only daily observations that included the indicators "Serving waste", "Plate waste" and "Number of portions" were included. Applying this filter reduced the number of total observations to 3222, of which 187 observations were made during the implementation period. All of the observations were manually validated to have potential errors omitted. The baseline duration is long in order to capture the natural variation in food waste. The yearly average ranged from 66.8 g to 74.2 g per portion. However, behind these averages is a large variation where individual canteens could report between 4.9 and 464 g per portion for daily observations.

### 2.2. Interventions

Four interventions were selected by the public catering managers in collaboration with the researchers and these interventions were implemented in parallel during summer-autumn 2020, followed by a food waste quantification period to determine the effects of the interventions.

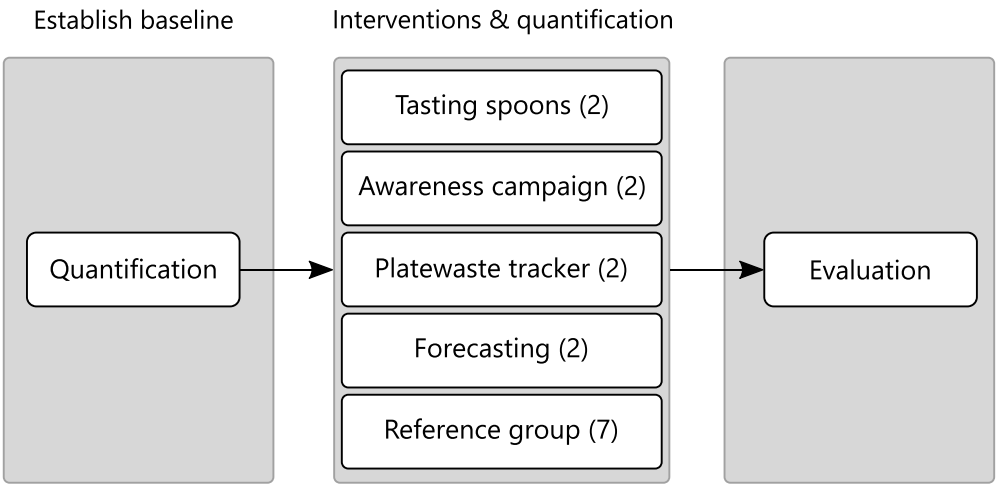


**Fig. 1.** Different steps of the analysis, ranging from data collection to evaluating the effect of the interventions. Values in brackets show number of school canteensin which each intervention was tested.

During this period the canteens were operating normally and COVID-19 did not impact the dining activities with the exception of queuing systems for keeping distance being in place and that students and staff with symptoms having to stay at home (substitute staff would then be called in). Each of the interventions were introduced in at least two school canteens, while the remaining canteens within the catering organisation acted as a reference group where no intervention took place. Three of the interventions primarily focused on addressing plate waste, whereas one primarily targeted serving waste. The interventions were implemented during a seven-week period, with food waste quantification taking place during the last two of these seven weeks.

The public catering managers selected school canteens to test each intervention, with the remaining canteens forming the reference group. Thus, there was no random selection, but rather selection based on expected willingness to implement new tools or compliance to the will of the kitchen manager. This selection approach represents an implementation strategy that could be applied by other large catering organisations, rather than relying on individual choices by scientists or canteen staff. It is likely that the selection approach favoured test objects with the highest interest and awareness (and least in the food waste problem), rather than those with the greatest potential for introducing the interventions.

### 2.2.1. *Tasting spoons*

The main idea of providing tasting spoons is to reduce plate waste and this intervention has shown promising results in other schools and establishments (Tocco Cardwell et al., 2019). The spoons allow guests to try a dish before scooping up too much food that may be left uneaten if it does not match the expectations of the guest. Tasting spoons also lower the threshold for guests to discover new types of dishes, as they can try a small piece without the risk of serving themselves too much. However, canteen staff must be made aware that reducing plate waste in this way might just shift the problem to serving waste if guests take less food than expected. This has to be taken into account to fully utilise the intervention of using tasting spoons. During the implementation, several trays of disposable tasting spoons were placed on top of the serving stations during lunchtime in two school canteens (Fig. 2).


**Fig. 2.** Tray of tasting spoons above one of the options in a school canteen serving line.

#### 2.2.2. Awareness campaign

Running an awareness campaign is a widespread intervention to reduce food waste (Pinto et al., 2018; Visschers et al., 2020). The idea is that if people are aware of food waste issues, they will take action to waste less. Awareness campaigns are often a one-way communication, with posters or table talkers spreading the message to the guests or staff. In this study, the intervention "awareness campaign" was aimed at school children in two schools and targeted plate waste reduction compared with previous years. Table talkers designed by the managers of the public catering organisation were placed on the tables (Fig. 3), and also on top of the serving stations, showing messages such as "Eat as much as you can – but throw away as little as you can". The table talkers also encouraged the school children to start with a smaller portion and then take a second helping, or to taste the dish prior to serving themselves if they were unsure whether they would like it.

#### 2.2.3. Plate waste tracker

To increase interactions with the guests, a plate waste tracker was introduced in two school canteens. The plate waste tracker is a kitchen scale connected to a tablet computer running dedicated software that interacts with the guests. The interface shows the guests how much food they are wasting and the impact of this waste (Fig. 4). The feedback to the guests as regards the impact is displayed as "Today we threw away 7.1 kg of food, which corresponds roughly to 21 portions or 27 cinnamon buns". The tablet computer allows the guests to provide feedback on why they wasted food, with some predefined alternatives: "I did not like it/it was not to my taste", "I took too much food" and "I did not have time to finish my meal". The kitchen also has the ability to set a goal that its guests should not waste more than a certain mass of plate waste per day.

The goal with introducing the plate waste tracker was to reduce plate waste compared with baseline.

#### 2.2.4. Attendance forecasting

Forecasting of attendance to gain a better picture of demand is an intervention that can help canteens in determining the number of guests for which they should provide food (Malefors, 2021). Public catering canteens often prepare food for all children enroled in the school, whether they show up or not, resulting in surplus food that is often wasted if not used for another meal. Previous studies have shown that using forecasting can reduce serving waste and help to save money in meal planning (Garre, Ruiz, and Hontoria, 2020; Malefors, Secondi, Marchetti, and Eriksson, 2021a; Ryu and Sanchez 2003; Yurtsever and Tecim 2020).

The two school canteens where the intervention "attendance forecasting" was introduced received a daily forecast of the number of guests that would attend lunch. At the end of the week, the head chef received a forecast for the coming week they could take into consideration in their meal planning and when ordering necessary food ingredients. The forecasting model used was based on a neural network, as described by Malefors et al. (2021b).

The goal of introducing attendance forecasting was to reduce serving waste compared with previous years.

### 2.3. Reference group

The reference group consisted of seven canteens that had no active measures in place to reduce food waste during the test intervention implementation phase in autumn 2020. The reference was used to examine whether the test interventions actually reduced food waste, or whether reductions were due to other trends and ambitions that would have happened in any case. However, since quantifying food waste can also act as a measure to reduce food waste (Eriksson et al., 2019), the reference group was not completely without active measures. The interventions needed to reduce food waste to a greater extent than in the reference group before any actual effect related to the intervention could be claimed, additional to effects from general awareness, waste quantification etc.

One complicating factor as regards the reference group was that its members had to have the same initial level of food waste, since a high initial level would create easier opportunities for reduction according to Obersteiner, Gollnow, and Eriksson (2021) and Eriksson et al. (2019). The difference in initial food waste level between the test groups and the reference group was quite small, but this variation still posed a potential risk of affecting the accuracy of the results. A greater risk was that many of the school canteens included in the study had low initial waste, at least in comparison with that reported by Obersteiner et al. (2021) and Eriksson et al. (2019), and their potential to reduce food waste is likely to be small. Thus the results are probably underestimates of the potential of the test interventions, and higher reduction potential is likely if the

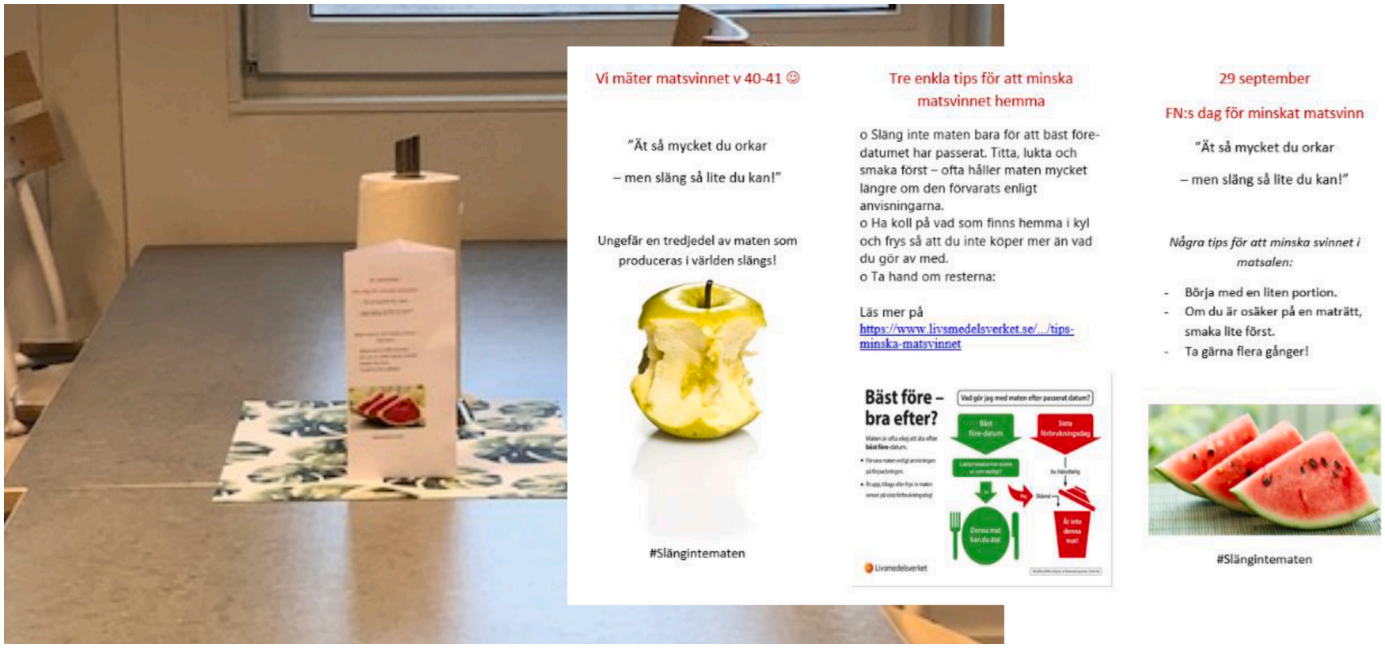


**Fig. 3.** Table talkers communicating messages on the issue of food waste to school canteen guests, as part of the awareness campaign intervention.

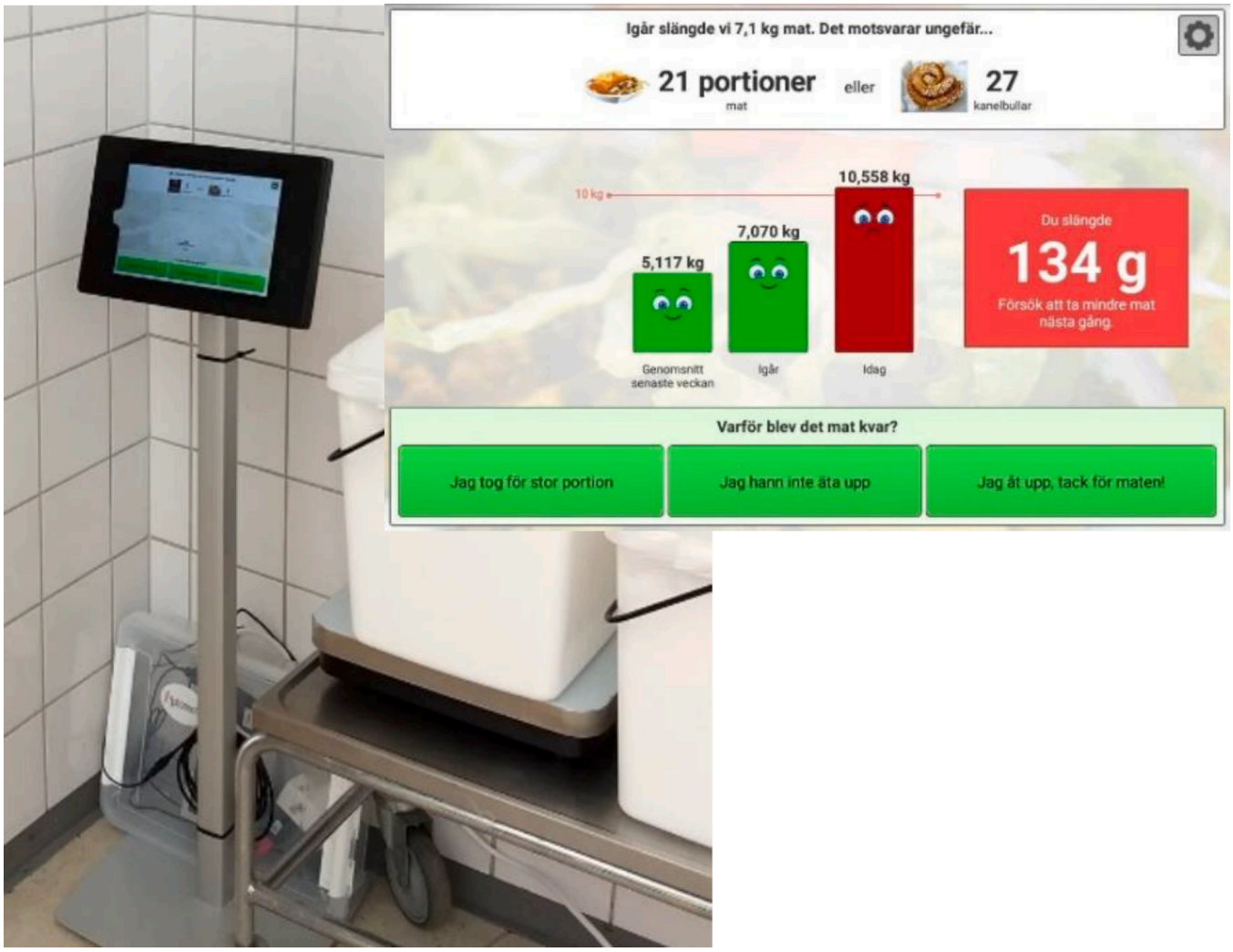


**Fig. 4.** Plate waste tracker at the point where school canteen guests scrape their plates. The interface communicates the target that the canteen has set and also shows how much plate waste was generated previously. The impact of the waste is shown in indicators that guests can relate to, such as "Yesterday we threw away 7.1 kg, which is roughly the same as 21 portions or 27 cinnamon buns". The interface also allows guests to give feedback on why they wasted food.

interventions are tested in canteens with higher initial waste. To test for differences between the test groups and the reference group with regards to knowledge, a short survey was conducted on the head chefs of the participating canteens. The responses were also used to identify any discrepancies between staff perceptions of their own workplace and actual observations made during the implementation period. The head chefs were asked what sort of food waste (plate waste or serving waste) they have most of, how large portion sizes they serve and how many daily guests they serve on average. The portion sizes were considered correct if they were within 100 g of the true (observed) value and the number of guests was considered correct if it was within +/−10% of the true value.

### 2.4. Evaluation of interventions

The method for analysing the efficacy of food waste reduction from the interventions was performed in grams per guest for all of the four interventions divided into plate waste, serving waste and total waste

(which also included waste from the kitchen if this was quantified). This was done by calculating the median values for the different waste processes with a median confidence interval of 95% for the levels of food waste before and after the intervention to determine which interventions had a significant reduction of food waste. All of the analyses were performed with the statistical software R.

## 3. Results

### 3.1. Result from the interventions test

The findings from the different interventions, divided into total waste, serving waste and plate waste per portion, are presented in Fig. 5.

The awareness campaign targeting guests and plate waste in the school canteens gave a significant reduction in plate waste. The median waste per portion for the plate waste fraction before implementation of the intervention was 37 g per portion (with 134 observations), while after the intervention was implemented it was 24 g per portion (with 15 observations), a 35% reduction. Serving waste and total waste were also reduced in the canteens that implemented the awareness campaign, but not significantly. Providing tasting spoons to allow guests to taste the food before serving themselves to reduce plate waste also resulted in a significant reduction in plate waste. Before implementation, the median plate waste per portion was 27 g (with 218 observations), while after the intervention was implemented it was 21 g per portion (with 14 observations), a reduction of 22%. This intervention also resulted in a reduction in total waste per portion but, due to overlapping uncertainties, no significant difference was seen. However, the median level of serving waste increased after introducing the tasting spoons, from 25 g per portion to 30 g per portion (a 20% increase).

After introducing the plate waste tracker targeting plate waste, both

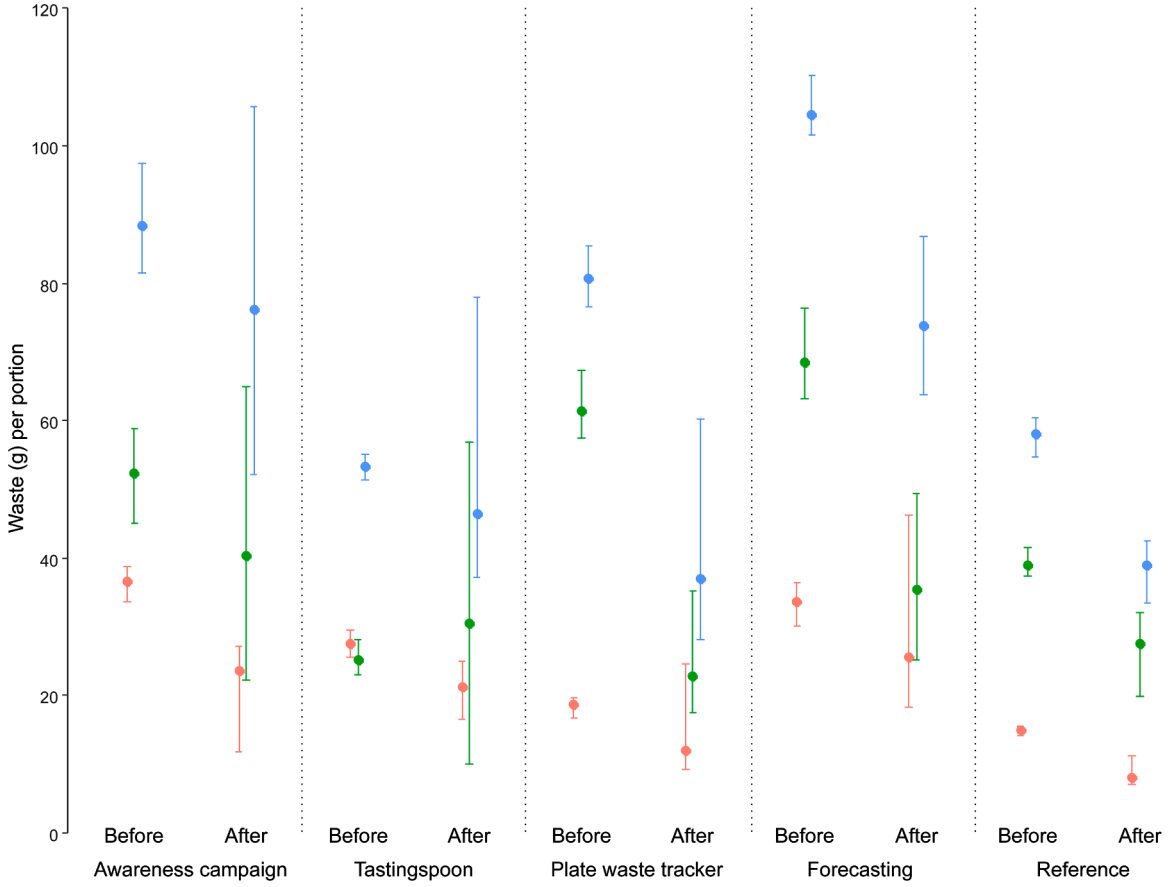


**Fig. 5.** Waste (g) per portion (median values with uncertainties as 95% confidence intervals) before and after implementation of measures to reduce food waste in school canteens. ● Total waste per portion, ● serving waste per portion, ● plate waste per portion.

total waste and serving waste per portion were significantly reduced. The plate waste tracker gave the largest waste reduction of all interventions (Fig. 6). A reduction from 19 g of plate waste per portion before the tracker was implemented (243 observations) to 12 g per portion after implementation (19 observations) was observed, which corresponded to a reduction of 37% (although not statistically significant). The reduction in serving waste is a possible spill-over effect, with serving waste reduced from 61 g per portion to 23 g per portion (62% reduction) in the canteens where the plate waste tracker was introduced.

The idea of introducing forecasting was that canteens would get a better picture of future demand and plan accordingly, reducing overcatering and serving waste. The serving waste for the canteens implementing this intervention showed a significant reduction, from an initial 69 g per portion (243 observations) to 35 g per portion (20 observations) after the implementation, a reduction of 49%. Serving waste (69 g per portion) and total waste (104 g per portion) were both initially highest for the canteens that implemented forecasting, indicating that these canteens might have the greatest problem to start with and therefore the greatest potential for reduction.

The canteens in the reference group also showed a significant reduction in all waste processes. The number of observations was 805 before the implementation phase and 60 during the autumn quantification period. Total waste per portion (which also included kitchen waste if this was quantified) before the evaluation period was 58 g per portion and this was reduced to 41 g per portion, a reduction of 29%, the serving waste fraction went from 39 to 28 g per portion, a reduction of 28% and plate waste was reduced from 15 to 7 g per portion a reduction of 53%. Since the canteens in the participating public catering organisation generally achieved a reduction in their levels of food waste over the years for which data were available, the interventions implemented had to be better than the general reduction trend observed for the reference group. This concept is illustrated in Fig. 6, which shows the difference in waste reduction per portion for the different waste processes, per measure, before and after the intervention quantification phase. As can be seen, only the awareness campaign (food waste reduction of 13 g per portion) and the canteens that implemented forecasting (reduction of 8 g per portion) achieved a greater reduction for plate waste compared with the reference group. The canteens that implemented the plate waste tracker reduced plate waste to the same extent as the reference group, with both resulting in a plate waste reduction of 7 g per portion compared with the previous quantification periods. Using tasting spoons reduced food waste by 6 g per portion for the plate waste fraction.

The reduction in serving waste achieved by forecasting was 34 g per portion compared with before implementation. However, the canteens that used the plate waste tracker reduced serving waste even more, by 38 g per portion, even though that intervention is not intended to reduce this type of waste. Canteens that implemented the awareness campaign also reduced their serving waste compared with the reference group, but not to the same degree as seen for the forecasting and plate waste tracker interventions.

Further, canteens that implemented the plate waste tracker and forecasting had a larger reduction in their total waste per portion compared with the reference group. Canteens that implemented the awareness campaign and the tasting spoons reduced total waste per portion less than the reference group (see Fig. 6).

### 3.2. *Agreement between kitchen staff perceptions and quantified results*

On examining the results from the quantification period in autumn

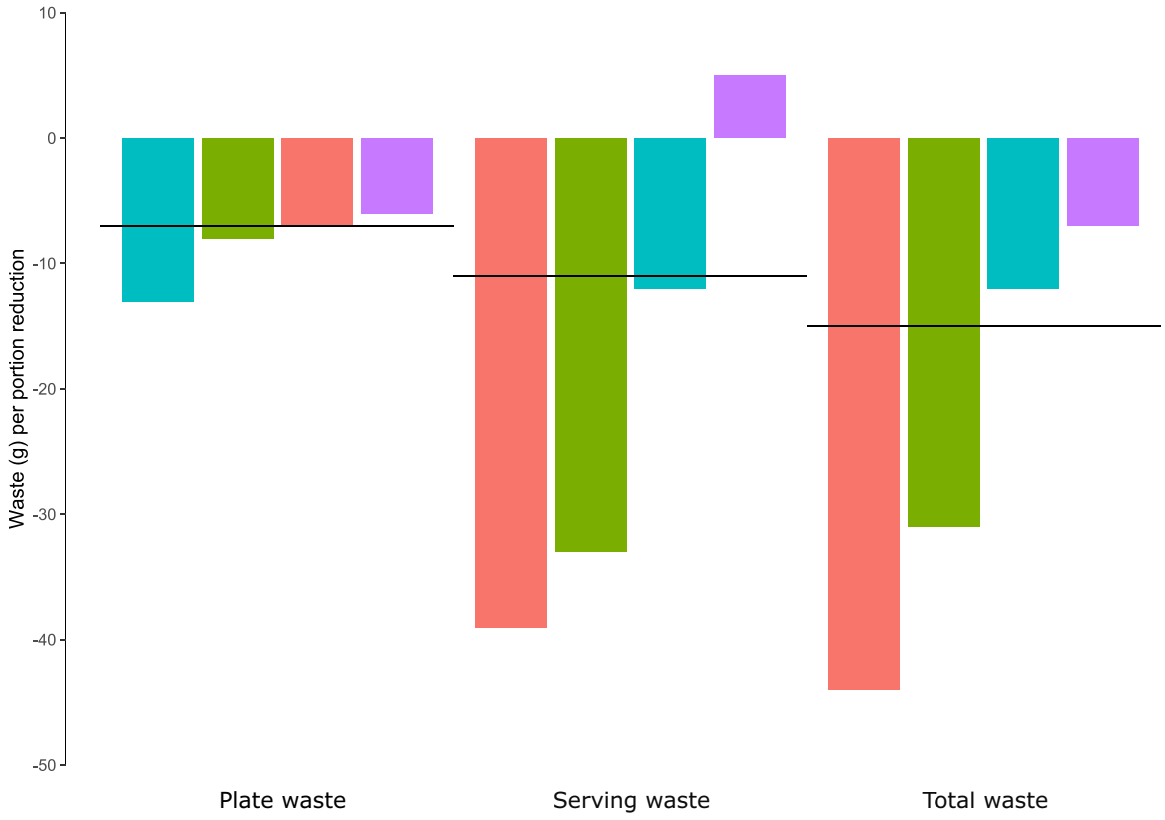


**Fig. 6.** Median reduction in food waste (g) per portion after implementation of the interventions: ■ Awareness campaign, ■ forecasting, ■ plate waste tracker, ■ tasting spoons, in relation to the reference group ▬, for plate waste, serving waste and total waste per portion. Total waste also included waste from the kitchen if this was quantified.

2020 for the public catering organisation and comparing the results to the perceptions of the head chefs, it emerged that all school canteens except one had a greater problem with serving waste than plate waste (Table 1). Seven out of 12 canteens also had an accurate perception that their main problem was with serving waste. When it came to understanding how many guests on average attended the meals, seven of the canteens (S2, S5, S6, S7, S8, S10 and S12) gave answers that were within 10% of the actual value. The greatest difference was found for canteens S4 and S11, which overestimated the number of guests by 52% and 67%, respectively. Half of the canteens that contributed data had a good understanding of portion sizes. One canteen did not know the portion size and another canteen did not manage to quantify the amount of food served, which is necessary to calculate the portion size. Canteen S9 reported a portion size of less than 100 g, but the quantified results showed that it was actually 288 g. Three canteens were unable to give a response to the questions, due to the ongoing pandemic situation and had to focus on the main operations of the canteen.

When the school canteens were grouped according to the intervention they tested, it was possible to calculate the average number of correct answers within the group (where answers where available). Using this simple compilation, the group with the highest level of knowledge was that using the awareness campaign, with an average of 2.5 correct replies out of 3 possible. This was followed by the users of attendance forecasting (average 2/3), the reference group (average 1.75/3), users of the plate waste tracker (average 1.5/3) and lastly the tasting spoon users (average 1/3). This shows that there was quite wide

**Table 1**
Responses from canteen head chefs compared with actual quantified data. Canteens S13, S14 and S15 were unable to answer due to the pandemic situation.

| Kitchen | Most food waste | | How many daily guests | | Average portion size | |
|---|---|---|---|---|---|---|
| | Answer | Quantified | Answer | Quantified | Answer | Quantified |
| S1 | Plate waste | Serving waste | 170 | 215 | 201–300 | 258 |
| S2 | Plate waste | Serving waste | 1100 | 1036 | 201–300 | 308 |
| S3 | Serving waste | Serving waste | 240 | 214 | 201–300 | 218 |
| S4 | Serving waste | Serving waste | 220 | 145 | 301–400 | – |
| S5 | Serving waste | Serving waste | 130 | 139 | 201–300 | 288 |
| S6 | Plate waste | Serving waste | 175 | 168 | 301–400 | 332 |
| S7 | Plate waste | Plate waste | 360 | 336 | 100–200 | 410 |
| S8 | Plate waste | Serving waste | 224 | 207 | 201–300 | 211 |
| S9 | Serving waste | Serving waste | 96 | 85 | <100 | 264 |
| S10 | Serving waste | Serving waste | 82 | 81 | Don't know | 288 |
| S11 | Serving waste | Serving waste | 135 | 81 | 201–300 | 323 |
| S12 | Serving waste | Serving waste | 140 | 128 | 201–300 | 294 |
| S13 | – | Serving waste | – | 141 | – | 178 |
| S14 | – | Serving waste | – | 138 | – | 216 |
| S15 | – | Plate waste | – | 113 | – | 297 |

variation of how well the knowledge of the head chefs was aligned with the quantified data. The reference group was ranked in the middle, indicating that it was comparable to the other test groups. There was no obvious pattern indicating that better knowledge would increase or decrease the potential for waste reduction.

## 4. Discussion

All interventions tested in this study achieved a reduction in the levels of food waste compared with the baseline quantification, with the magnitude of the reduction ranging from 6 to 44 g/portion. The participating public catering organisation has been active in quantifying its levels of food waste since 2014 and was therefore able to present quite a detailed picture of its current challenges in terms of food waste. Eleven of the 15 canteens studied generated most of their waste in the serving line, which corresponds well with findings in other studies (Eriksson et al., 2017; Getlinger et al., 1996; Silvennoinen et al., 2015).

The interventions evaluated in this study were chosen according to best available technology accepted by users in the catering organisation. Three of the interventions focused on plate waste reduction, which is not the greatest problem for the canteens studied but was still an important educational point. The three interventions that targeted plate waste probably also had a spill-over-effect on the staff in various forms. For instance, the plate waste tracker enabled staff to get an understanding of why meals were wasted on a daily basis, making it possible to adjust their planning, which in the long run might affect serving waste. In this study, the levels of serving waste were strongly reduced (by 62%, a reduction from 61 to 23 g per portion in the canteens that used the plate waste tracker, an intervention primarily designed to target guests and plate waste. The canteens that used the plate waste tracker already had low plate waste to start with (19 g per portion) and a reduction down to 12 g per portion represented a very low level of plate waste. To put this in perspective, Engström and Carlsson-Kanyama (2004) reported plate waste of 33–35 g per portion for two schools in the Stockholm region and the Swedish National Food Agency found the median value of food waste in Swedish school canteens to be 21 g per portion. This indicates that other kitchen units with high initial waste might benefit more from the plate waste tracker, since they have greater potential for reduction. Visschers et al. (2020) examined the effects of an awareness campaign and compared these with the effects of reducing plate size in two university canteens, and concluded that it was the reduced plate size that achieved a reduction in food waste, whereas the awareness campaign alone was not a sufficient measure to reduce food waste. In contrast, in the present study plate waste was actually reduced in the canteens that implemented the awareness campaign (from 37 to 24 g per portion, a 35% reduction). This may indicate that awareness campaigns affect age groups differently depending on how they are designed and whether other or prior measures have previously influenced the guests. However, both 37 and 24 g per portion, as observed in the present study, are normal levels of plate waste in Swedish school canteens according to previous studies (Engström and Carlsson-Kanyama 2004; Swedish National Food Agency, 2019a). Tasting spoons gave a statistically significant reduction from 27 to 21 g/portion, or 22%, in plate waste in the present study, but also created a tendency for a shift towards more serving waste. In a study by Tocco Cardwell et al. (2019), tasting spoons together with clear and consistent portioning instructions reduced the edible food waste fraction significantly. Tasting spoons in conjunction with awareness campaigns might be a cheap tool that canteens can implement rather easily as a starting point.

A clear limitation in this study was the use of non-randomised canteens when implementing the interventions.. However, it is hard to force canteens to use interventions that they don't believe in. For an organisation to implement tools to reduce food waste there needs to be trust in what the interventions are trying to achieve. Or the interventions need to be redesigned or readapted so they are accepted by the canteens. Therefore, compliance in using the interventions by the canteens might have interfered with the results. It should also be noted that there are always some actions taken to lower food waste in all 15 school canteensstudied, as kitchen staff continually try to keep waste levels low. These efforts may vary in intensity over time, and it is therefore difficult to exclude the possibility of other parameters acting within the organisation and on canteen level. This makes it difficult to evaluate the effects of interventions on food waste, as the reduction observed might not necessarily be attributable to implementation of the intervention alone. For instance, the participating organisation is challenging school children to waste as little as possible and awards the school with lowest plate waste a trophy called the "golden plate". Such gamification and nudging schemes, in conjunction with other types of simultaneous measures against food waste, might have an unexplored interactive effect. Our reference group reported that these interventions that are always running and some have quite a strong reduction effect. Thus the total waste per portion in the reference group before the interventions was 58 g per portion, which aligns well with previous reports of around 60 g per portion for primary schools (Malefors et al., 2019; Swedish National Food Agency, 2019a), and this was reduced to 41 g per portion (a reduction of 29%), to what can be considered a low level of food waste. The plate waste fraction for the reference group went from 15 to 7 g per portion (a reduction of 53%) and the serving waste fraction from 39 to 28 g per portion, a reduction of 28%.This indicates that the systematic work to reduce food waste in the municipality seems to be having an effect and that further interventions should be targeted at specific canteens that have identified potential problems. For instance, canteen S7 has identified that its largest problem is plate waste, so there is high potential for that canteen to target the plate waste fraction. Since problems with food waste are not the same for all canteens, they need to find their own individual solutions to their problems and design interventions accordingly, in this case some of the interventions examined did not perform better than the reference group, which indicates that the tailor made own interventions applied in the reference group are more effective and feasible than the interventions tested.

Since there is a flow of pupils through a school over time, all interventions directed at guests probably need to be of a recurring nature, so that the effects of the intervention are not lost when new pupils arrive and older pupils leave. The same may be true of canteen staff, and it should be noted that engagement, awareness and knowledge can be very individual and therefore change drastically due to staff changes.

For the forecasting intervention, which targeted serving waste, the intervention was overall successful, with a reduction of 49%. This is higher than the reduction of 20–40% anticipated by Malefors et al. (2021b), although it is difficult to isolate cause-effect relations in the type of experimental set-up used in the present study. The forecasting intervention might have been even more efficient if it had been implemented in canteens that actively acknowledge difficulties in planning the number of guests, instead of in canteens where managers decided which intervention they should implement. In future interventions, canteens S4 and S11 would probably be great subjects for a forecasting or ordering system, since they showed large deviations (52% and 67%, respectively) between anticipated number of guests and the real outcome.

The small questionnaire used in this study only asked three questions, but such a simple knowledge test could be used to identify potential problems that could be targeted by certain interventions, thus making the intervention more effective by aiming it at a specific problem. For instance, Filimonau and Coteau (2019) stress the importance of staff and managers reflecting on their role in waste generation, since they can take active decisions to guide the canteen and organisation regarding the food waste issue. Since serving waste is a large problem for some canteens and more efforts are needed to understand how already available tools, such as forecasting and other types of material (e.g. the one promoted by the USEPA (US EPA n.d.)) can be used to reduce this type of waste without shifting the waste to another process. However, plate waste interventions should not cease, as there is plenty of room for

multiple types of interventions to co-exist.

According to the survey results (Table 1), half of the participating canteens had a good understanding of a suitable portion size. The actual portion sizes quantified corresponded well with national mapping performed by the Swedish Food Agency (2019a), which reported portion sizes in the range 125–528 g, with a median value of 297 g per portion.

However, there is little knowledge of how much of the school meal is actually consumed, which means that the nutritional value of meals can only be followed up on an average level and makes it possible for individuals to eat very unbalanced meals. Swedish school canteens are making a transition to serving more plant-based options and cooking more food on-site with raw materials, which might generate more food waste in the future, but the waste would then originate from a diet that is more adapted to the planetary boundaries and from less resource-intensive production systems (Willett et al., 2019). Future studies need to assess the direction in which public catering organisations are heading in terms of sustainable diets and how well school children adapt to and accept these changes, since reduced food waste alone is not enough to make the food system sustainable. There is also a risk that increased efforts in food waste quantifications will reveal more food waste, thereby making it look like an increasing problem. In school canteens the food waste issue is two-fold, since the food that is wasted is supposed to provide nutrients to the pupils. However, even if food eaten is a priority, it is also important not to promote overeating, which can contribute to obesity and metabolic food waste (Ellison and Prescott 2021; Sundin, Rosell, Eriksson, Jensen, and Bianchi, 2021). Here pedagogic meals (teachers eating lunch together with pupils) can play an important role, since they are considered a way to build stronger relationships between children and adults, create a healthy attitude to food and generate curiosity about new flavours, foods and textures. This could ultimately increase acceptance of dishes served, increase consumption and even simultaneously reduce waste. Today, the pedagogic meal is still an untapped resource to a large degree, waiting to realise its full potential (Persson Osowski, Göranzon, and Fjellström, 2013; Skolmat Sverige, 2021). Previous studies have shown the effectiveness of presence of positive role models for establishing healthy food choices for children (Eliassen, 2011; Savage, Fisher, and Birch, 2007; Wechsler, Devereaux, Davis, and Collins, 2000), and further studies investigating the teacher role specifically have been suggested (Marty, 2017).

It should further be pointed out that, even though the interventions tested in the present study should be seen as the best available technology, all interventions were of a fairly simple nature, so they could be implemented and used for long or recurring periods by school canteens. As this study (and literature) shows, tools with the potential to reduce food waste are available, however, what is missing, is the large-scale use of these tools. What is needed is therefore policies that enforce reductions in food waste or, even better, reduced negative impact from the food system, where reduced food waste is one of many components. For efficient implementation, such policies need to be supplemented with sufficient means to reduce food waste, but also sufficient incentives for staff and organisations, to increase motivation. Our recommendation from the present study is that all Swedish public catering organisations should have access to a toolbox of interventions that could be used in individual canteens to solve individual problems, so that efforts are targeted where they can make the largest impact. There should also be checks to ensure that the tools are actually used. However, interventions need to deal with the complex problem of fostering good eating habits while also lowering food waste levels, since only by addressing both these problems simultaneously can sustainable development be achieved.

## 5. Conclusions

All four interventions tested (awareness campaign, forecasting, tasting spoons, plate waste tracker) reduced food waste, by 6 to 44 g per portion. However, the reference group also reduced its levels of food waste during the study period, indicating a general trend for reduced food waste in the participating canteens. For plate waste, the awareness campaign was the only intervention that reduced this fraction of food waste by more than in the reference group (by 13 g per portion compared with 7 g per portion). For serving waste, forecasting and the plate waste tracker resulted in a significant reduction, of 34 and 38 g per portion respectively, while the reference group achieved a reduction of 11 g per portion. For total waste per portion, the plate waste tracker and forecasting achieved greater reductions (44 and 34 g of per portion respectively) than the reference group (17 g per portion). The best interventions were therefore the plate waste tracker and the forecasting procedure, followed by awareness campaign and finally tasting spoons. Tasting spoons had a tendency to shift waste from the plate waste fraction to the serving waste fraction. This highlights that an intervention can have an expected effect on certain waste fractions but that there are spill-over effects to other fractions and therefore all fractions should be included in the evaluation to fully capture the overall performance. The interventions tested proved to be successful in the experimental setting (Swedish school canteens), but there is no guarantee that they would provide similar results elsewhere, and they might perform better if tailored to the needs of specific canteens. It is therefore a need to test the feasibility and implementation integrity of food waste interventions. Organisations need to have a toolbox of interventions that canteens with the largest scope for improvement can implement to solve a problem, thereby reducing food waste. With systematic and continuous use of food waste interventions, catering organisations have good potential to reduce their food waste and help create a sustainable food system.

## CRediT authorship contribution statement

**Christopher Malefors:** Conceptualization, Methodology, Visualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Niina Sundin:** Formal analysis, Writing – review & editing. **Malou Tromp:** Conceptualization, Methodology, Data curation, Writing – review & editing. **Mattias Eriksson:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing.

## 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 developed the interventions ‘plate waste tracker’ and ‘guest attendance forecasting’, and own the rights to these innovations through the company Matomatic AB. There is a potential conflict of interest as those authors have a financial interest in the two innovations.

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