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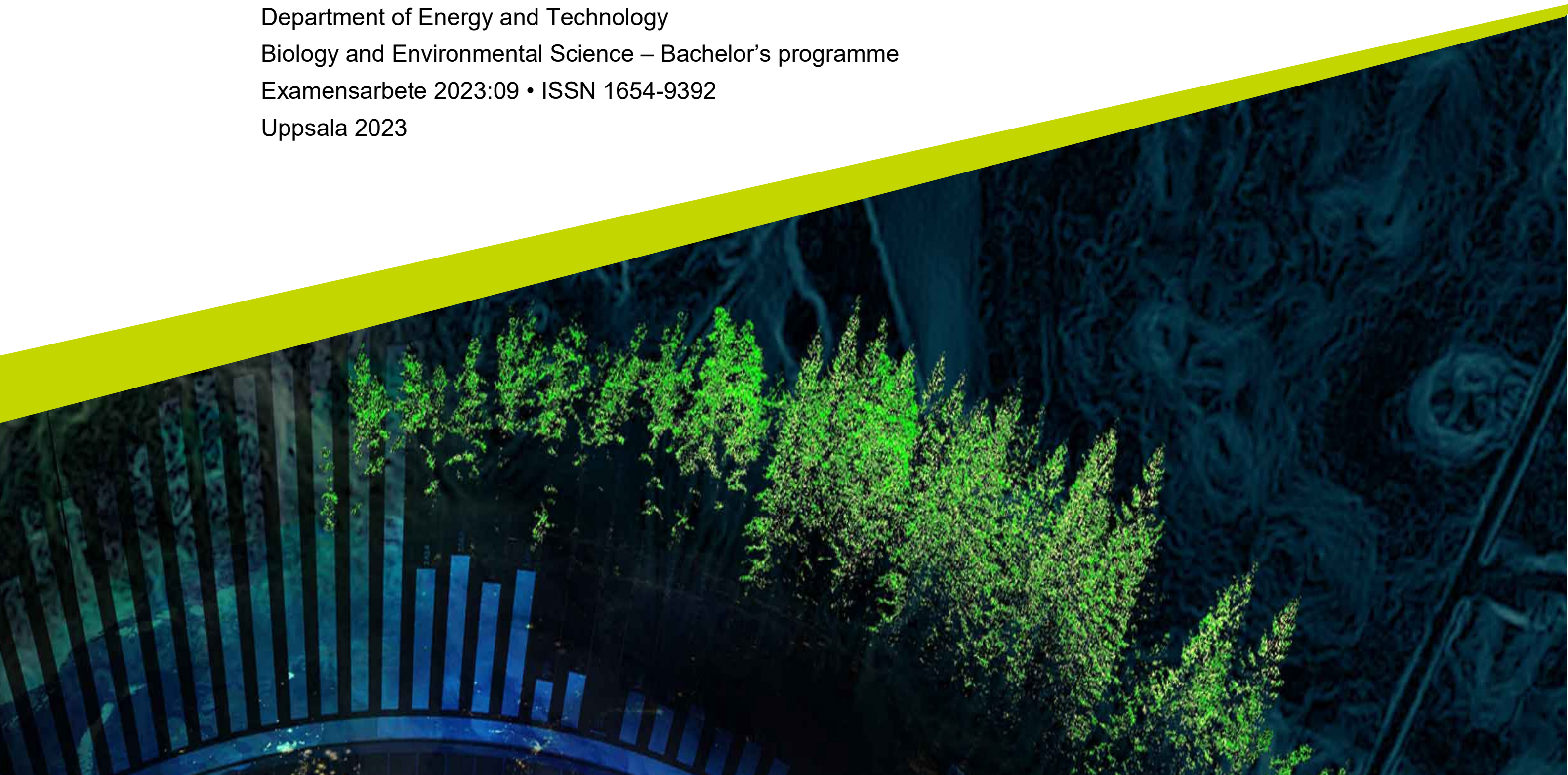

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Plockanalys på matsvinn från skolluncher med fokus på klimatpåverkan

Runa Halvarsson

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Abstract

Food waste has a great impact on the environment and generates approximately 3.3 giga tonnes of CO_2-eq annually. The SDG 12.3 set by the UN, to halve the global per capita food waste by 2030, is one of the measures that strives to combat this problem. There is a necessity to implement reduction measures across all stages of the food chain in order to reach this goal. In Sweden there is about 33 000 tonnes of food waste generated from public meals annually, with roughly 9 200 tonnes originating from elementary schools.

For this study, plate waste from two elementary schools in Uppsala, Sweden, was analysed with the aim of gathering knowledge into what food categories that are wasted in schools and their quantities. The aim was also to investigating the climate impact of the plate waste. Understanding more about plate waste could help implement measures to reduce it and to ensure that pupils receive their daily energy intake. The method of waste composition analysis was used for eight days over a two-week span to separate and weigh plate waste based on food categories. To assess the climate impact of the waste, a carbon footprint was used. The results were that pasta and potatoes were wasted the most at both schools. Vegetables, fish, meats, and bread were wasted in low quantities. However, beef had the highest carbon footprint of all observed food categories. Plant based foods had a small climate impact. In order to reduce their impact on the climate, the schools will have to implement further food waste reduction strategies. Future research should focus on how to address the problem areas that this study has discovered, in order to reduce food waste and the climate impact of school canteens without compromising the recommended nutritional meals that Swedish schools provide.

Keywords: Waste composition analysis, plate waste, climate impact, elementary schools, canteens

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Abbreviations

CF	Carbon footprint
CO_2-eq	Carbon dioxide equivalents
SDG	Sustainable Development Goals
WCA	Waste composition analysis

1. Introduction

1.1 Background

About a third of all food produced globally is either lost or wasted (FAO 2011). This has devastating consequences for the planet, in light of the fact that the lost food accounts for about 3.3 giga tonnes of CO2-eq. These numbers do not include the carbon footprint (CF) of land use change, which means the real numbers could be even higher. Reducing food loss and waste is necessary in order to attain a sustainable food system (FAO 2017), and there are goals in place to reach this aspiration. For example, the UNs Sustainable Development Goal (SDG) 12.3, which states that global food waste at retail and consumer level should be halved per capita by 2030 (SDG 12 Hub n.d.). SDG 13, which strives to combat climate change, will also be positively affected by a decrease in global food waste. Food waste can be used as an energy source, for example to produce biogas, which lowers the climate impact of the waste. However, it is more important for the environment to not produce food that will be wasted since the production of food has a large environmental impact (FAO 2013, 2017; Scherhaufer et al. 2018). In the EU, the majority (73%) of climate impact from food waste comes from production (Scherhaufer et al. 2018). Food production is also a large contributor to eutrophication, acidification (Scherhaufer et al. 2018), and biodiversity loss (FAO 2013).

Estimates show that 88 million tonnes of food waste are generated in the EU annually (Stenmarck & Jensen 2016). Scherhaufer et al. (2018) assess that food waste within the EU generates about 186 million tonnes of CO2-eq, which represents 15.7% of the food systems climate impact. The EU is committed to reducing food waste and to reach SDG 12.3 and have taken actions towards doing so (Directorate-General for Health and Food Safety n.d.). One such action is the EU-funded project LOWINFOOD, in which actors from many disciplinaries work together to test innovative solutions towards reducing food waste. The projects' main goal is to create more sustainable value chains in the fruit and vegetable, baked goods, and fish sectors by reducing food waste. LOWINFOOD targets both at-home and out-of-home consumption (CORDIS 2022).

Sweden also has goals of its own to combat food waste. The interim target which states that the country's total food waste should decrease with 20% by mass per capita between the years 2020-2025 (Sveriges miljömål 2023) is one of them. The target has not been achieved yet and there are uncertainties whether it will be reached in time. The target is related to the Swedish environmental objectives Reduced Climate Impact and A Good Built Environment. According to the Swedish Environmental Protection Agency (2022), public meals in Sweden gave rise to 32 900 tons of food waste in 2020. Malefors et al. (2022a) found that food waste from Swedish school catering ranged between 19,000-23,000 tonnes the same year. Out of those, 9 200 tons came from elementary schools (Swedish Environmental Protection Agency 2022).

Earlier studies have found that food waste in Swedish schools varies between 33-79 g/portion (Engström & Carlsson-Kanyama 2004; Eriksson et al. 2017; Malefors et al. 2022a). In 2020, Malefors et al. (2022a) found the average food waste per portion in elementary schools to be 42 g/portion. Persson Osowski et al. (2022) observed in a recent study on four Swedish schools that plate waste accounted for the second highest amount of food waste after serving waste. Eriksson et al. (2017) and Malefors et al. (2022b) have also found serving waste to be the largest factor of food waste in schools. Silvennoinen et al. (2015) received similar results for Finnish communal food services. Serving waste is especially high in satellite kitchens because there is little flexibility to adjust the amount of food that is produced (Eriksson et al. 2017; Steen et al. 2018; Persson Osowski et al. 2022). Plate waste refers to everything that a guest has left on their plate. This can be edible food, inedible food such as peels and bones, or other waste like napkins (Malefors et al. 2019). Eriksson et al. (2017) found that the amount of plate waste does not differ based on kitchen type. Therefore, there is a possibility that waste prevention measures for reducing plate waste can be applied without regard to kitchen type.

It is important to reduce all food waste to attain a sustainable food system (Sveriges miljömål 2023). To do this, there is a necessity of understanding the reasons why food waste occurs. Even though plate waste isn't the biggest contributor, it is still a part of a food system that needs to become more sustainable. Plate waste is also an indicator that nutritious food is left uneaten. In Sweden, school lunches are free of charge and required to be nutritionally balanced according to law (Riksdagsförvaltningen n.d.). The Swedish Food Agency (2019) is responsible for national guidelines that applies to school lunches. Therefore, food waste in schools cannot be reduced simply by decreasing production, as each child has a right to receive a meal that is nutritionally balanced and fulfils 30% of their daily energy requirement.

Quantifying food waste is only the first step towards reducing it, and while Sweden has reached a high degree of implementation on this matter (Malefors et al. 2022a), there are still factors that are unknown. This study strives to fill this gap in knowledge by examining the composition of plate waste at Swedish schools in Uppsala municipality. The results of this study will provide a valuable insight into what foods that are wasted most in Swedish schools, so that problem areas can be addressed and hopefully combated. The weight per food item will also provide a better understanding of the climate impact that the schools have a potential to reduce.

1.2 Waste Composition Analysis

To know the composition of food waste, some method of separation is necessary. One such method is waste composition analysis (WCA), where there are several existing guides that one may consider (E.g. Williams 2021). WCA is a method where food loss and waste are separated into categories and weighted (Food Loss and Waste Protocol 2016; Avfall Sverige 2019; Williams 2021; Commission for Environmental Cooperation n.d.). Avfall Sverige (2019) did a WCA where 43 schools and preschools from three Swedish municipalities participated, and found that edible food waste varied between 27-94 g/portion. They also found that food waste can be reduced to 20 g/portion.

The use of a waste-tracking tool can help to reduce food waste (Engström & Carlsson-Kanyama 2004; Goossens et al. 2022; Malefors et al. 2022b), and is also a method which allows for observation that in turn can lead to identification of problem areas (Silvennoinen et al. 2015). While WCA is a method which gives insight into the specifics of food waste, it does have limitations. For example, the WCA method provides no data on liquids or the causes for food waste (Silvennoinen et al. 2022). Separating and weighing plate waste is still an uncommon practice due to being time demanding and usually expensive (Liz Martins et al. 2014).

1.3 Carbon footprint

To assess a climate change impact from the plate waste at elementary schools in Uppsala, a CF data was used. For the calculations, Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel v 2.1 (2022) was used. The list presents an approximated climate impact for different foods which have been estimated with the life cycle assessment method (LCA) according to ISO 14040. The list is connected to the Swedish Food Agency's food database and is based on Swedish standards. Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel v 2.1

(2022) provides an average value of the climate impact of a food category, and not for any specific product. The calculated CF applies to uncooked foods. The values do not take packaging into consideration. For imported foods, a general transport to Sweden is accounted for. No transportations within Sweden are part of the system boundaries.

1.4 Objective and research questions

The objective of this thesis is to study what food categories and their quantities that are thrown away by pupils in two elementary schools in Uppsala and to investigate the climate impact of that food waste. In order to do this, this study will consider the following questions:

- How much plate waste is generated from each school, and what are the proportions of the foods that comprise the waste?
- Are there any significant differences between the schools' plate waste?
- What is the carbon footprint of the generated plate waste?

2. Materials and methods

2.1 Schools

For this study, two elementary schools in Uppsala, Sweden, were examined. The schools will be referred to as school A and school B. School A had worked with the LOWINFOOD project prior to this study, where they used waste-tracking devices and educational meals as food waste reduction measures. The schools have satellite kitchens and receive their lunches from a larger school in the area. Both schools have the same menu (which can be found in Appendix 1) with a few exceptions. All of the menu options are seldom served at smaller schools, which is true for the schools in this study. The menu repeats every six weeks. According to personnel, the canteen at school A has about 300 guests each day while school B has 320-330 guests. These numbers include 6–9-year-olds and teachers. Both schools have routines in place to create a calm environment during lunch time. After all students have fetched their meals, a ten-minute silence is enforced.

Semi-structured interviews with kitchen personnel were conducted before the WCA started. This provided background information for the present study about when lunch is served, their estimation of the amount of guests that usually attend lunch service, and how much food waste that is normally generated. School A serves lunch between 11.00-13.00, giving all classes 30 minutes each to eat. In school B, lunch is served between 10.40 to circa 12.30. Grades 1-3 each have 20 minutes for lunch while the six-year-olds have between 30-40 minutes. The personnel at school A estimated that their waste amounts to 10 kg at most but that it is often lower. The amount was said to depend on what food is served as the students enjoy some meals more than others. At school B, personnel estimated that food waste add up to 4-8 kg a day. Kitchen staff counted plates for all days of WCA which provided numbers for daily guests served. A list with the amounts of ordered food per day per school was obtained. Both schools ordered the same amount of potatoes, 30 kg, and rice, 15 kg, for lunch on the days when those options were served (see Appendix 1).

The schools were chosen because of their similarities in size and pupils' ages, and due to their willingness to participate. A further inclusion criterion was that one of the schools had participated in the LOWINFOOD project while the other one had not.

2.2 Data collection

Data was collected for eight days in total over a two-week span from both of the schools. Only plate waste from lunch services was analysed. The dates for food waste collection were the 11-14th, the 17-19th as well as the 21st of April in spring 2023. No food waste was collected on the 20th because soup was served, and it was assumed that separation would be difficult since the bread would most likely absorb the soup. The schools were closed on Monday the 10th as it was a public holiday. Both schools supplied their plate waste in plastic garbage bags. To collect the plate waste, a large plastic bag was used with a plastic container inside (see figure 1) to provide a stable surface during transport. Waste from school B was retrieved around 12.30 PM by foot and transported to the location of the WCA. Afterwards, the waste from school A was collected around 13.00 PM. The plate waste was then transported on foot to the nearest bus station where bus was used to transfer it to the sorting site.

2.2.1 Wate Composition Analysis

Firstly, the plastic bags with the total plate waste each day were weighted separately. The weight of the plastic bags was considered and removed during calculations. A scale with 0.01 kg accuracy was used during the study (see figure 2). All results were recorded on a pre-prepared excel sheet. The WCA was executed using a table with plastic tubs, which acted as containers for the plate waste to be sorted into (see figure 3). While using plastic gloves for protection, the waste was separated by hand into different piles based on food categories such as pasta, chicken, or bread (see Appendix 2 for a complete list of categories that were compiled for each day of the study). The waste was also divided into edible food waste or unavoidable waste. Peels from eggs and fruit, as well as fruit cores, were classified as inedible waste, and will be referred to as Inedible food waste. Napkins and butter packages got sorted into a pile which is hereon referred to as Other (see table 3). After separation, the containers with the food categories were weighted separately with the tare function on the scale being used between each weighing. The food category with the most weight, usually the carbohydrate of the day, was left in the plastic bag and weighted while still in it. The weight of the bag was redacted during calculations.

The supervisor of this study took part in the first day of sorting (11th of April 2023). The possible separation level within each food category was decided on in unison that day. Because of limited time and resources, as well as the liquid foods, it was not possible to do a complete separation. The WCAs were completed in four to seven hours each day, including retrieval of the food waste plus disposal and cleaning time. The containers were cleaned between each day as to not weigh food waste from the previous day.

Figure 1. Plastic bag and storage bin which were used to collect plate waste from the schools. A garbage bag with plate waste is placed inside the storage bin.

Figure 2. Scale with a plastic container containing plate waste placed on top (food category: mixed vegetables).

Figure 3. Plate waste that has been separated into different containers based on food categories. Taken on the 11th of April 2023. Photographer: Niina Sundin

2.3 Calculations

2.3.1 Carbon footprint

The CF per kg food stuff that Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel v 2.1 (2022) provides was multiplied with the measured weight per food category. The value for spaghetti was used to calculate a CF for pasta, as these were the available numbers for pasta. For pasta and rice, there is a significant difference in weight between the uncooked and the cooked product. To receive more reliable results, numbers from KF och ICA provkök (2000) were used recalculate the cooked weight that was measured during WCA to the original dry weight. Tagliatelle, which was the closest category to spaghetti, increases from 100 g of uncooked pasta to 280 g cooked. For Jasmin rice, the weight increases from 85 g to 235 g during cooking. Using the more accurate weights for calculating CF affected the results greatly and it was deemed necessary for these food categories. For the Bolognese (table 12 in Appendix 2), a value for minced meat was used where it was assumed that the meat consisted of 50% pork and 50% beef. Since the Bolognese had the highest climate impact, its weight was also recalculated to represent the uncooked product before multiplying with the CF from Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel v 2.1 (2022). Since the minced meat in Bolognese is boiled in sauce it was assumed that the meat had reduced 40% in weight from cooking. The number 40% was chosen as it is a median between 35-45, which are the percentages given by KF och ICA provkök (2000). No other food categories than pasta, rice and the Bolognese were recalculated to their uncooked weight. It was deemed that the results for CF would not differ much for other categories. It is also difficult to know which vegetables that were served cooked or not as most vegetables were weighed together, despite if they were food waste from the salad buffet at the schools or from the main dishes. Also, the CF for the breads that Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel v 2.1 (2022) provides are already baked.

The same value for cheese was used for both feta and cottage cheese, which were the cheeses recorded during the WCA, since Öppna listan – ett utdrag från RISE klimatdatabas för livsmedel (2022) provides one value for cheese. To attain a CF for vegetables, a median was calculated from the values of spinach, green peas, tomatoes, and iceberg lettuce. This is because these are the vegetables that the list presents.

After calculating an approximate CF per food category for both schools, the total CF for each school was calculated. The total CFs were then divided with the total plate waste that each school had generated to attain a CF value per kg plate waste.

Sauces could not be taken into consideration during calculations as they could not be separated during the WCA, meaning their weights were not recorded separately.

2.3.2 Statistical analyses

Excel was used to calculate totals, mean values, and standard deviation for the number of portions, the amount of plate waste, and the amount of plate waste per portion. To calculate the amount of edible waste, the weight of Inedible food waste and Other were subtracted. The list that kitchen staff provided which contained the weight of ordered food per day per school made it possible to calculate what percentages that the plate waste represented from the total food produced. The p-values for the recorded weights of plate waste and for the weights of the food categories were calculated with the t-test function in excel.

The number of portions at school B on the $11^{th\ of}$ April 2023 was calculated as a median from the portions during the rest of the waste collection. This is because kitchen staff provided a value that later was declared to be too low.

3. Results

3.1 Waste Composition

The total plate waste collected from school A was 69.3 kg during the 8-day period, out of which 64.62 kg (93%) was edible food waste. The average plate waste was 8.7 kg per day, as shown in table 1. Waste per portion was 29.3 g on average. Plate waste at school A amounted to 12% of the total food served (69.3 kg out of 594.7).

Table 1. The recorded portions, total plate waste, and waste per portion at school A during the days of WCA. The table includes calculated median values and standard deviation.

Date	Portions	Total plate waste (kg)	Waste per portion (g)
2023-04-11	320	7.7	24.2
2023-04-12	342	9.6	28.0
2023-04-13	306	9.5	30.9
2023-04-14	278	8.0	28.9
2023-04-17	261	7.7	29.7
2023-04-18	283	9.6	34.1
2023-04-19	290	10.5	36.3
2023-04-21	297	6.6	22.2
Median	297 ± 25.5	8.7 ± 1.3	29.3 ± 4.7

The plate waste collected from school B amounted to a total of 64.3 kg, with 61.6 kg (96%) being edible. Table 2 shows that the average plate waste at School B was 8.0 kg per day while waste per portion was 25.4 g on average. School Bs plate waste accounted for 11% of the total food produced (64.3 kg of 559.7) during the days of analysis.

Table 2. The recorded portions, total plate waste, and waste per portion at school B during the days of WCA. The table includes calculated median values and standard deviation.

Date	Portions	Total plate waste (kg)	Waste per portion (g)
2023-04-11	317	8.8	21.5
2023-04-12	312	9.6	30.8
2023-04-13	324	9.9	30.5
2023-04-14	310	6.5	21.0
2023-04-17	309	8.9	28.9
2023-04-18	315	8.3	26.2
2023-04-19	325	7.7	23.7
2023-04-21	324	6.6	20.3
Median	317 ± 6.6	8.0 ± 1.4	25.4 ± 4.3

The food category that school A wasted most was pasta (31%) followed by potatoes (19%), see figure 4 and table 3. The least wasted options were beans and chickpeas (0% or 0.1 kg) and olives (1%).

The students at school B wasted pasta the most out of the recorded food categories (29%), as shown in figure 5 and table 3. Potatoes were the second most wasted food category (21%). Beans and chickpeas were wasted the least (1%).

Table 3. Total plate waste weight per food category. Only food categories that coinsided with both schools are included in the table. The total plate waste was higher, see table 5-12 in Appendix 2 for the weights of all recorded food categories.

Food category	School A (kg)	School B (kg)
Pasta	19.2	17.8
Potatoes	12.0	13.1
Rice	5.7	5.6
Chicken	1.4	1.5
Pork	0.9	1.0
Bolognese	1.2	1.2
Fish	2.5	2.7
Vegetarian option	7.0	8.6
Mixed vegetables	5.7	4.4
Beans and chickpeas	0.1	0.3
Olives	0.9	0.9
Bread	2.1	1.5
Inedible food waste	3.8	2.3
Other	0.8	0.4
Total	63.4	61.4

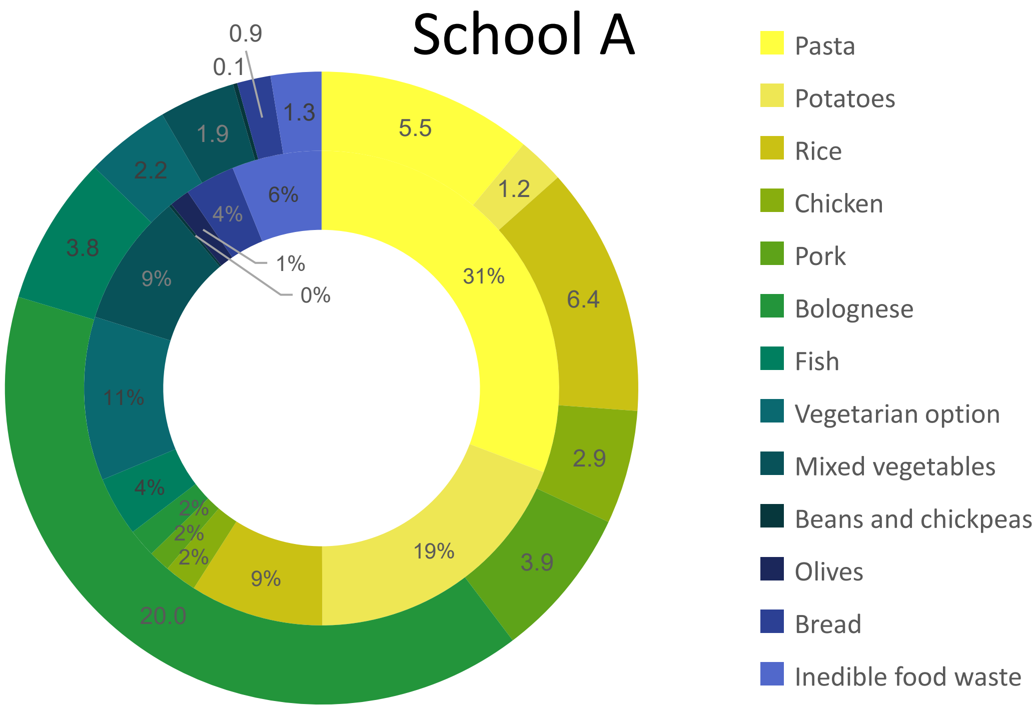

Figure 4. The inner circle shows percentages of food categories from the total plate waste from the 8-day period from school A. The legend shows colour codes for the food categories. The outer circle shows kg CO_2-eq per food category. Note: The carbon footprint for olives is included in the value for mixed vegetables, as there was no available data for olives.

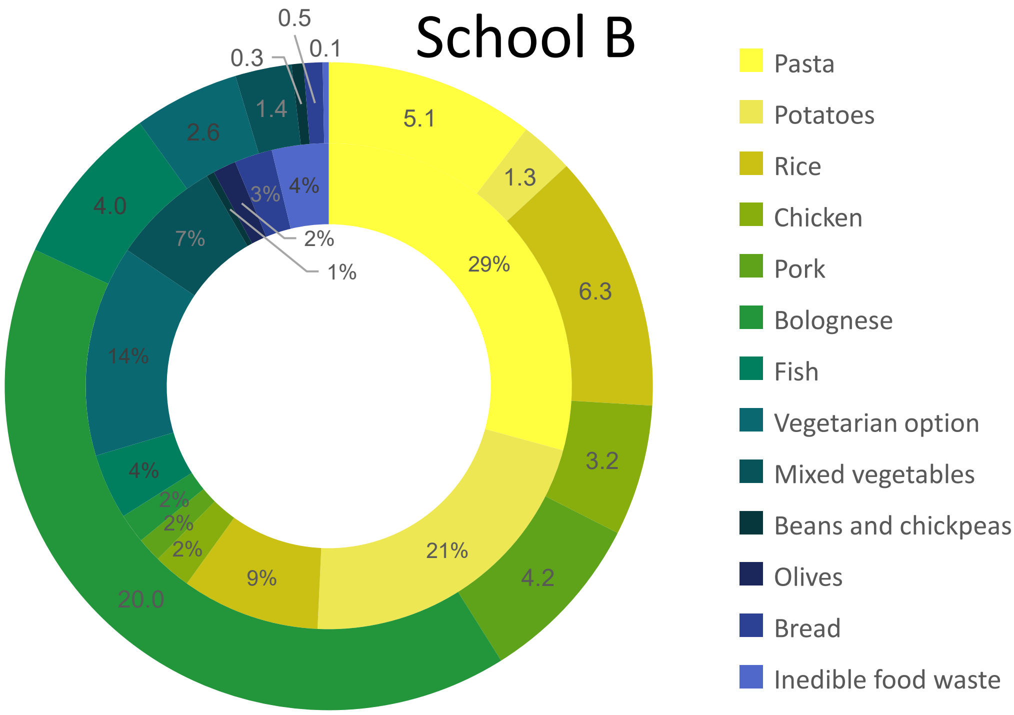

Figure 5. The inner circle shows percentages of food categories from the total plate waste from the 8-day period from school B. The legend shows colour codes for the food categories. The outer circle shows kg CO_2-eq per food category. Note: The carbon footprint for olives is included in the value for mixed vegetables, as there was no available data for olives.

3.1.1 T-test

The calculated p-value between the schools' plate waste was 0.37, thus, no significant difference between the amount of waste was detected.

The p-value between the food waste components was 0.89, which also holds no statistical significance.

3.2 Carbon footprint

The total plate waste from the eight days of collection generated about 98.7 kg CO_2-eq. School A generated 51.1 kg CO_2-eq with standard deviation 4.8, and school B generated 48.9 kg CO_2-eq with a standard deviation of 4.9. This is 0.7 kg CO_2-eq per kg food waste at school A and 0.8 kg CO_2-eq per kg food waste at school B.

The food category with the highest CF is Bolognese, which was served on the 21$^{st\ of}$ April. This is labelled "Kökets val", or kitchens choice, on the menu from figure 8 in Appendix 1. Both schools managed to waste 1.2 kg Bolognese as plate waste (table 12 Appendix 2), which had a CF of 20 kg CO_2-eq per school (figure 4 and 5). The Bolognese represented 40% of the CF from school A and 41% of the CF from school B. Jasmine rice has the second highest CF, slightly over 6 kg CO_2-eq per school. The amount of wasted rice was 5.7 kg from school A and 5.6 kg from school B. The CF from pasta was 5.5 kg CO_2-eq at school A, where 19.2 kg were wasted, and 5.1 kg CO_2-eq from school B, who wasted 17.8 kg pasta.

The food categories with the lowest CF were Quorn at school A (see weight in table 5 Appendix 2) and remains from apples at school B (the Inedible food waste in figure 5). The inedible parts of apples also had the lowest CF of all food categories with 0.2 g CO_2-eq in total. Apples could be found in the collected plate waste on 6 out of 8 days of analysis (table 5-12 Appendix 2).

4. Discussion

The carbon footprint per kg food waste in this study ranged between 0.7-0.8 kg CO_2-eq. The food category with the highest CF was Bolognese (50% beef, 50% pork), which accounted for 2% of the total plate waste at both schools (figure 4 and 5). Beef was served once during the eight days of analysis. The schools' six-week menu schedule showed that beef is only served twice during that period, and sometimes a third time if it is the kitchens choice as in this study. Rice had the second highest CF, which could be lower since the curry sauce added to the recorded weight. However, as the CF of the curry sauce could not be calculated, the approximated CF from the rice could be assumed to represent both the rice and the sauce. Similar assumptions were made for all sauces throughout the analysis. It was deemed acceptable because the CFs provided by Öppna listan – ett utdrag ur RISE klimatdatabas för livsmedel v 2.1 (2022) show that rice and heavy cream, an ingredient that is commonly found in sauces, do not have big differences in their CF. Potatoes were wasted in high quantities but had a very low climate impact (figure 4 and 5).

School A had a higher CF than school B, which is to be expected since their total plate waste was higher. However, school B had a slightly higher CF per kg plate waste. School A had a CF for bread which was almost double the amount that school B had. Another difference in CF between the schools are those from fruits, which were counted as Inedible food waste since only peels and cores were found in the plate waste. This can be accredited to the fact that school A served a lot of oranges during the WCA, which are an imported good in Sweden, while school B served apples, which can be produced locally.

What can the schools consider doing to reduce their CF, without compromising the quality of the meals? As previous studies suggest (Engström & Carlsson-Kanyama 2004; FAO 2013; Scherhaufer et al. 2018; Silvennoinen et al. 2022), some foods such as meat contribute to a large CF despite being wasted in small amounts. The results of this study are in line with this since the Bolognese contributed to the most CO_2-eq despite being wasted in small amounts. The schools do not serve beef very often, as told by their six-week menus, so it might be difficult for them to reduce it further. Perhaps it could be served only once every six weeks instead if there is no possibility of removing beef from the menu completely. Other protein-rich foods with a lower CF could be served in place of beef. However, it is more important to implement measures to prevent the students from throwing away food with a large CF. As mentioned previously, the produced food is made to be nutritious and with children's energy needs in mind (Swedish Food Agency 2019; Riksdagsförvaltningen n.d.). If not already implemented, the schools could increase education about different foods climate impact and food waste as it has been shown to reduce waste (Engström & Carlsson-Kanyama 2004; Malefors et al. 2022b; Mariam et al. 2022).

To decrease the CF from the rice, the school could serve Swedish oat rice, which has a lower climate impact than the Jasmin rice from Thailand (RISE 2021). In this case however, the schools already serves oat rice on other days according to the 6-week menu. It would be interesting to compare the amount of waste between the different types of rice at the schools. If the oat rice is less liked by the pupils, and therefore wasted more, it might not be a good idea to use it as a supplement for Jasmin rice. Less options could be served to reduce waste and therefore the schools climate impact, as Eriksson et a. (2017) have shown that more menu options lead to an increase in food waste. If this can be applied to sides as well as the main dish, then school A could stop serving both soft bread and crisp bread to reduce their plate waste. This change, however, might impact the students experience of the school lunch. The schools can also consider what fruits to serve. If possible, locally grown foods such as apples can be served to reduce their climate impact. These changes would only have a small effect however, as bread and fruit (Inedible food waste) had low climate impacts compared to other food categories at the schools.

School A wasted slightly more grams per portion than school B (table 1 and 2). The proportions of the recorded food categories were very similar between the schools (see figure 4 and 5). Carbohydrate-rich foods such as pasta, potatoes and rice were wasted the most at both schools. Pasta was observed in the food waste on five days throughout the study and potatoes were found on three separate days (see table 5-12 in Appendix 2). The schools wasted the same proportions of meat and fish. If the side salad categories (mixed vegetables, beans and chickpeas, and olives) are added then both schools wasted equal percentages in this category as well (figure 4 and 5). School B wasted a higher percentage of the vegetarian options than school A. School A wasted more bread than school B, which could be because school A served both soft bread and hard bread. The same theory could be applied to Inedible food waste, as the plate waste from school A contained fruit more often than the waste from school B, as well as eggs of which none were found in the plate waste from school B. All conclusions are drawn from the observed plate waste, and it is possible that more options were served at School B that did not become plate waste.

The calculated p-value between the schools' plate waste showed that there was no statistical significance between the schools. No statistical significance was seen between the weights for each food category between the schools either. These results strengthen the notion that there is no difference between the types of food waste between the schools. Even though school A have worked with LOWINFOOD, school B have also implemented internal measures to reduce food waste. Except for educational measures, having enough time to eat can also lower food waste (Silvennoinen et al. 2015). Steen et al. (2018) identified that the students age, and the noise and stress level in dining halls are the two main reasons for increased plate waste. It was also found that plate waste increases as children become older. Large portions were a factor that increased both plate and serving waste, which was due to overproduction. Satellite kitchens especially need help to reduce overproduction by receiving more accurate numbers of dining guests, since they have less options to adjust the already ordered amount of food (Eriksson et al. 2017; Steen et al. 2018).

The results of this study are in line with the results from Silvennoinen et al. (2015), where food waste from 23 schools and day-care centres were gathered over a 5-day period. The food waste was collected from school lunches and consisted of waste from cooking, serving, and plate waste (named customer leftovers). The food waste was then analysed by researchers over an 8-day period to find out the quantity and composition. The results were that 63% of the plate waste from schools and day-care centres consisted of main courses. For the main vegetarian courses, the value was much lower at 3%. Salad added up to 16% of the leftovers while bread made up 4% of the total. Silvennoinen et al. (2015) also had a category named Other, of which 11% of the plate waste was accounted for. Silvennoinen et al. (2015) examined liquids, which this study did not, and results found that milk represented 4% of the examined waste. For this study, 69% of the plate waste was made up of the carbohydrate rich foods (pasta, potatoes, and rice) and the different meats (chicken, pork, and beef) and fish that were served during analysis. This is comparable to the category "Main course" from Silvennoinen et al. (2015), which was 63% as previously stated. The percentage of bread is also comparable between the studies, as School A and School B wasted 4% and 3% bread. Less vegetables were wasted during this study, 10% for both schools compared to the 16% that Silvennoinen et al. (2015) recorded. However, a higher percentage of vegetarian options was recorded in the plate waste from this study. The results for vegetarian option in this study could be unreliable since there was only one day during the study where this was the only option for main dish (the 12th of April, see figure 7 in Appendix 1 and table 6 in Appendix 2). In the six-week menu, one day each week is reserved for only vegetarian options. If another one of these days were examined, there is a possibility that the proportions of the vegetarian options compared to other food categories could be either lower or higher. It is possible that the pupils simply dislike the vegetarian option that was served during this study (see table 6 in Appendix 2). The recorded weight of vegetarian options were quite low during the other days of analysis. For the examined Finnish schools, the total food waste amounted to 58 g/portion (Silvennoinen et al. 2015). Out of the total food produced during the study, 5.7% accounted for customer leftovers. In this study, 12% of the total food produced became plate waste. Those 12% however also include inedible food waste and thrash that was found amongst the food. Silvennoinen et al. (2015) included a separate category for vegetable peelings and bones, which accounted for 3.9% of the total food produced. The Swedish and Finnish school systems both use self-serving buffets for lunch, which have requirements on nutritional value (Riksdagsförvaltningen n.d.; Oy n.d.). Because of the similarities between Swedish and Finnish school lunches, the results are comparable to each other.

Results from Engström and Carlsson-Kanyama (2004) also found that potatoes, rice and pasta made up the largest fraction of plate waste. Vegetables accounted for the second most plate waste while meat and fish were wasted the least. The study included two Swedish schools which were analysed for two days during lunchtime. One of the schools' plate waste was 33 g/portion. This is close to the results of this study, where plate wasted varied between 25-29 g/portion on average. The second school that Engström and Carlsson-Kanyama (2004) examined included serving waste as part of the plate waste, and is therefore not relevant for this study.

There are some uncertainties to this study which could have an impact on the results. Even though some research was done before conducting the WCA, the time limit of this study prohibited professional experience from being acquired beforehand. The time limit was also a reason for uncertainties in the weighing results from the WCA. Some school meals took a very long time to separate, for example when hash was served (see figure 6), which limited the degree of separation. It was also impossible to separate liquids from the rest of the food waste as mentioned previously. To achieve more accurate results, more resources would be necessary. To minimize sauces mixing with the plate waste, one could collect the plates directly from the students in the school canteen. This, however, could affect the food waste behaviour of the students. In this study, the separation was deemed to be accurate enough since the proportions of the plate waste were of interest. Further, a more extensive list of CF for specific food groups would be necessary to calculate a more accurate CF.

Another uncertainty may be the scope of the analysis. For more reliable results, it could be of interest to conduct a WCA over a longer time period. In the present study, two weeks of school lunches were examined out of the six-week schedule that the schools have for repeating menus. Since the composition of the plate waste was very similar from day to day, and between the schools, it is difficult to know whether a longer study would provide different results. For the current objective, eight days were deemed to provide results that are accurate enough. However, if different age groups were to be examined, the plate waste might present other proportions of the wasted food categories. The results of this study can only give an insight into the plate waste from elementary school children between the ages of 6-9 in Uppsala municipality. It could also be of interest to study whether the results would change if more elementary schools were examined. School A and B are similar in size and are situated in the same neighbourhood. They also had similar routines during lunch service. If larger elementary schools in Uppsala were analysed it might affect the results, especially if more students contribute to a stressful dining environment which in turn can increase food waste (Steen et al. 2018).

Figure 6. Plate waste, hash with chicken and carrots. Picture is taken after separation was completed, however there are several carrot cubes that were left due to time limits.

There are several uncertainties in the calculated carbon footprint values. For example, Öppna listan – ett utdrag ur RISE klimatdatabas för livsmedel v 2.1 (2022) have calculated the CF for lentils and apples of Swedish origin. There were no investigations into the origin of ingredients in this study. The list also provides the CF of uncooked ingredients, which means that the climate impact of the plate waste should be higher when accounting for the energy used for cooking. Another uncertainty is the CF for vegetables since a median was used. It is difficult to say whether this value is a good estimation or not. The estimated value was accepted since all the vegetables had much lower climate impacts than other food categories. The recalculations for the weights of pasta, rice, and minced meat (Bolognese) means that not all approximated CFs are equally representative of the food categories actual CF. As previously explained, these categories were chosen as they affected the results to a high degree.

In Appendix 1, all the tables have a row named “loss”. This demonstrates when small portions of plate waste got lost during the weighting-process in the WCA. In some cases, too much food was weighted. This could be due to uncertainties with the food waste tracker or the human factor. These numbers are all very small and should not affect the results as the proportions wouldn’t change with such small quantities. The calculated CF would also be unaffected by these small quantities.

For future studies, it would be interesting to include liquids in a similar fashion to Silvennoinen et al. (2015). Future research should also focus on measures that reduce food waste and as a result the climate change impact of our food systems. In EU food systems, beef is the product with the highest impact not only in terms of CF but also when it comes to acidification potential and eutrophication potential (Scherhaufer et al. 2018). FAO (2013) also highlight that meat potentially has a significant impact on biodiversity because of the land take that occurs during production. It would therefore be of interest to look into the extensive environmental impact of plate waste at schools in future studies, as this study only estimates a climate impact.

According to the Swedish Food Agency (2020), every kg of food waste in Sweden generates about 1.6 kg CO_2-eq. This value comes from a study where Scholz et al. (2015) analysed discrepancies between food waste quantity and CF of perishable food products from Swedish supermarkets. The Swedish Food Agency writes that this was the only available value at the time of publication. The present study found that the CF for 1 kg of plate waste is about 0.7-0.8 kg CO_2-eq. This value is significantly lower than that provided by the Swedish Food Agency. Therefore, it should not be applicable to use a CF from supermarket food waste as a general value for all sorts of food waste in Sweden. The results from Scholz et al. (2015) were that 85% of the wasted mass were fresh fruit and vegetables and that 4% were meat products. These are not the same proportions that the present study have found for plate waste in schools. It is clear that there is a lack of research on the CF of food waste in Sweden. Food waste can vary greatly between sectors (Swedish Environmental Protection Agency 2022), and therefore have different climate impacts. This is also a matter to explore for future studies.

Food waste occurs as the result of various factors (Heikkilä et al. 2016; Steen et al. 2018; Persson Osowski et al. 2022), and it can be difficult to know what measurements will have the most effect. However, reduction measures have been studied (Vizzoto et al. 2021; Malefors et al. 2022b; Persson Osowski et al. 2022) and will most likely continue to be so in order to continue reducing food waste from public meals. If food waste trends continue to decline, and if school canteens are given the tools to prevent and reduce food waste, then it is possible for this sector to achieve the global and national goals that are set (Malefors et al. 2022a).

5. Conclusion

School A generated 69.3 kg plate waste during the eight days of analysis in this study. School B generated 64.3 kg plate waste, which is slightly less than school A, despite having a higher amount of guests served. The mean g/portion for the schools were 25.4 (school B) and 29.3 (school A). There was no stastistical signifficance between the schools plate waste, and the proportions of plate waste between the different food categories were very similar. Pasta made up the biggest proportion of the plate waste, between 29-31%, while beans and chickpeas made up the smallest fraction of the plate waste for both schools.

The total plate waste that was collected during the study generated a carbon footprint of 98.7 kg CO_2-eqvivalents. For every kg food waste, the carbon footprint was 0.7-0.8 kg CO_2-equivalents. Even though pasta made up the largest portion of the collected plate waste, it was Bolognese, or rather beef, that had the highest climate impact. The Bolognese respresented only 2% of the plate waste at each school, but about 40% of the generated climate impact. To reduce this impact on the climate, beef could be replaced with other meats or vegetarian products that are high in protein and meets the requirements for school meals in Sweden. It is, however, of even more importance that measures are taken to reduce the plate waste at the schools, as the food is supposed to be consumed. Further studies should focus on plate waste-reduction measures in order to combat this problem. Continued research on this specifik subject should include more schools and ages in order to receive results that are more respresentative for schools in Uppsala.

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Appendix 1

Meny grundskola
Vecka 15

MÅNDAG	Annandag påsk	**10 APR**
Dagens extra Inga måltider serveras		
Dagens gröna Inga måltider serveras		
Dagens rätt Inga måltider serveras		
TISDAG		**11 APR**
Dagens gröna Pasta med ratatouille		
Dagens rätt Röd lasagne och keso		
ONSDAG		**12 APR**
Dagens gröna Röd currygryta med quorn och basmatiris		
Dagens rätt Röd currygryta med fläsk och basmatiris		
Dagens extra Röd currygryta med kyckling och basmatiris		
TORSDAG		**13 APR**
Dagens gröna Broccoligratäng med kokt potatis		
Dagens rätt Fiskgratäng med tacosmak och kokt potatis		
FREDAG		**14 APR**
Dagens gröna Krämig blomkål och kokosgryta med bulgur		
Dagens rätt Yakinikukyckling med grönsaker och nudlar		
		Powered by Mashie

Figure 7. Menu for school lunches at School A and School B between the 10th to the 14th of April 2023 (Matsedel n.d.).

Meny grundskola
Vecka 16

MÅNDAG	**17 APR**
Dagens gröna Pasta med ost- och broccolisås	
Dagens rätt Pasta med ost- och skinksås	
Dagens extra Pasta med ost- och kalkonsås	
TISDAG	**18 APR**
Dagens gröna Rotfruktspytt med ugnsbakade rödbetor	
Dagens rätt Kycklingpytt med kall currysås	
ONSDAG	**19 APR**
Dagens gröna Grönsaksplättar med limesås och kokt potatis	
Dagens rätt Fiskgratäng thai och kokt potatis	
TORSDAG	**20 APR**
Dagens gröna Morotssoppa med hembakt bröd	
Dagens rätt Mannagrynspudding och hemkokt sylt	
Dagens extra Kökets val	
FREDAG	**21 APR**
Dagens gröna Kökets gröna val	
Dagens rätt Kökets val	

Powered by Mashie

Figure 8. Menu for school lunches at School A and School B between the 17th to the 21st of April 2023 (Matsedel n.d.)

Appendix 2

Table 5. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Tuesday the 11th of April 2023.

Food category	School A (kg)	School B (kg)
Rice with red curry sauce	5.68	5.6
Chicken	0.42	0.6
Quorn	0.1	
Pasta	0.32	
Mixed vegetables	0.52	0.22
Olives	0.26	0.22
Chickpeas	0.18	0.08
Friarelli pepper	0.09	
Feta cheese	0.02	
Bread	0.18	0.08
Other	0.04	0.04
Total	7.63	6.78
Loss	0.11	0.04

Table 6. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Wednesday the 12th of April 2023.

Food category	School A (kg)	School B (kg)
Lasagne (vegetarian)	5.98	8.5
Chicken	0.14	
Pasta	0.38	
Mixed vegetables	0.56	0.48
Olives	0.14	0.34
Chickpeas		0.12
Friarelli pepper	0.02	
Orange peels	1.04	
Pancake	0.16	
Bread	0.86	0.08
Other	0.16	0
Total	9.58	9.52
Loss	0	0.08

Table 7. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Thursday the 13th of April 2023.

Food category	School A (kg)	School B (kg)
Fish, pieces	0.74	0.4
Boiled potatoes	3.26	3.42
Fish stew and potato, mushy (inseparable)		2.54
Fish stew and rice, mushy (inseparable)	2.14	
Burger (beef)	0.04	
Sausage (pork)		0.08
Lasagne (vegetarian)	0.54	
Mixed vegetables	1.04	0.64
Olives		0.2
Chickpeas		0.1
Carrots	0.22	
Lemon, including peels	0.86	1.66
Apple, including peels and core		0.36
Egg	0.16	
Pancake	0.08	
Bread	0.2	0.42
Other	0.18	0.08
Total	9.46	9.9
Loss	0	-0.02

Table 8. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Friday the 14th of April 2023.

Food category	School A (kg)	School B (kg)
Noodles	4.7	4.92
Chicken	0.28	0.42
Meatball	0.08	
Mixed vegetables	1.2	0.98
Olives	0.08	0.06
Carrots	0.24	
Lemon	0.4	
Orange	0.82	
Apple core		0.04
Egg	0.02	
Bread	0.08	0.12
Other	0.08	0
Total	7.98	6.54
Loss	0.02	-0.02

Table 9. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Monday the 17th of April 2023.

Food category	School A (kg)	School B (kg)
Pasta and sauce	5.74	7.18
Ham	0.92	0.82
Hamburger		0.02
Mixed vegetables	0.58	0.48
Olives		0.12
Carrots	0.22	
Chickpeas	0.04	
Butter beans		0.04
Lemon, including peels	0.04	
Apple, including peels and core		0.1
Feta cheese	0.08	
Egg	0.08	
Bread	0.18	0.02
Other	0.1	0.14
Total	7.76	8.92
Loss	-0.02	0

Table 10. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Tuesday the 18th of April 2023.

Food category	School A (kg)	School B (kg)
Hash (potato, curry sauce, some vegetables that were difficult to separate)	4.14	6.06
Chicken	0.5	0.5
Meatballs	0.04	
Ham	0.22	
Vegetarian meat substitute (unknown)	0.02	
Mixed vegetables	0.54	0.88
Olives	0.18	
Carrots	0.3	
Chickpeas	0.08	
Apple core		0.1
Egg	0.16	
Eggshell	0.08	
Bread	0.2	0.3
Other	0.06	0.02
Total	9.52	8.28
Loss	0.12	-0.02

Table 11. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Wednesday the 19th of April 2023.

Food category	School A (kg)	School B (kg)
Fish gratin	1.8	2.26
Boiled potatoes	4.6	3.62
Chicken	0.04	
Meatballs		0.16
Vegetable patties	0.34	0.08
Mixed vegetables	1.06	0.58
Olives	0.08	
Carrots	0.36	
Butter beans		0.04
Appel core		0.1
Egg	0.04	
Pancake	0.14	
Bread	0.3	0.34
Other	0.12	0.06
Total	10.42	7.74
Loss	0.1	-0.04

Table 12. Plate waste from school A and school B in Uppsala divided into observed food categories and weighted. Collected on Friday the 21st of April 2023.

Food category	School A (kg)	School B (kg)
Spaghetti and sauce	4.96	4.82
Bolognese	1.08	1.02
Sausage		0.1
Mixed vegetables	0.16	0.12
Olives	0.12	
Friarelli pepper		0.18
Appel core		0.04
Cottage cheese	0.02	
Egg	0.02	
Bread	0.14	0.18
Other	0.08	0.08
Total	6.58	6.54
Loss	0	0.04

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