Quantifying household food waste

A comparison between methods

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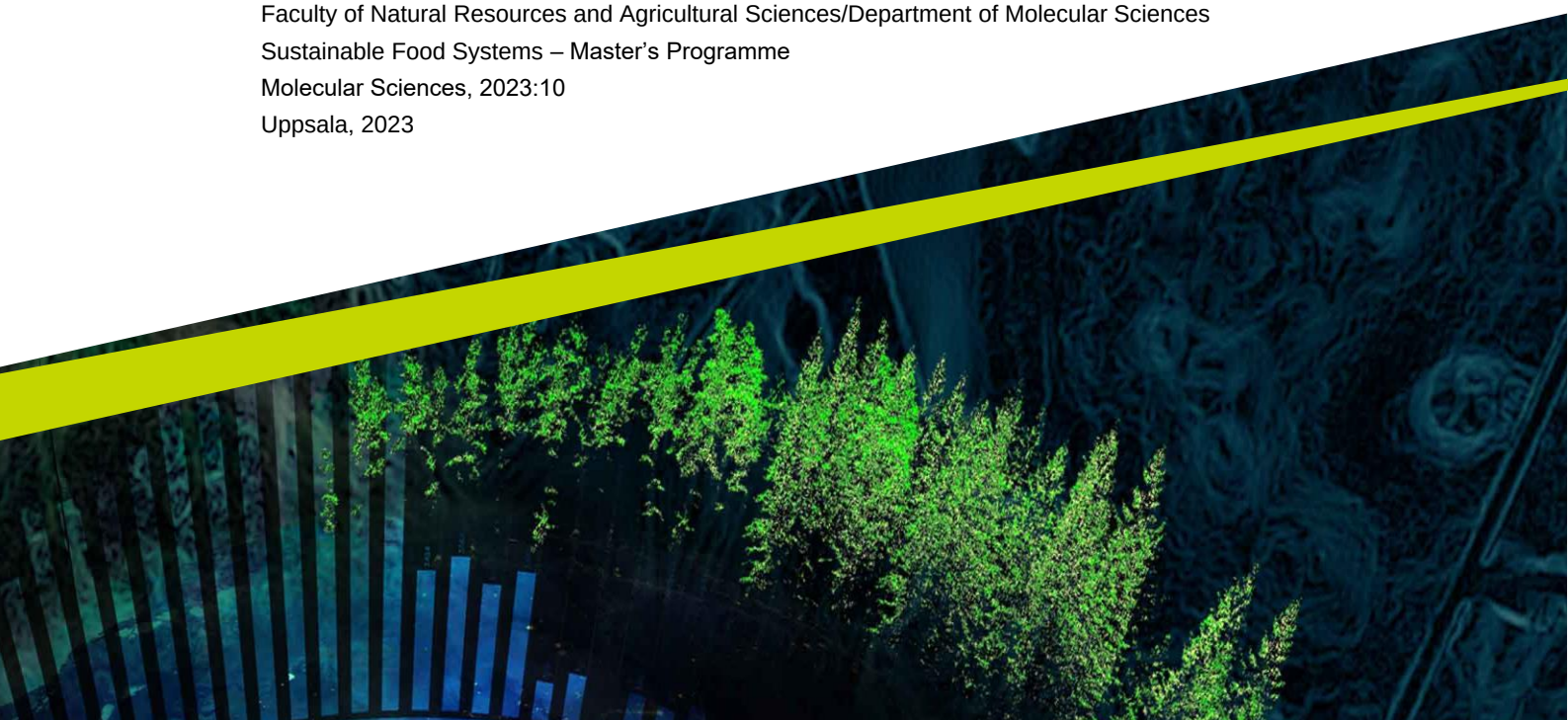

Quantifying household food waste. A comparison between methods

Kvantifiering av matsvinn i hushållet. En jämförelse mellan metoder.

Sophie Jakobsson & Amanda Sjölund

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Abstract

Having significant impacts on the environment, societies, and economies all over the world, the global food system is linked to many challenges related to sustainable development. Food waste constitutes one problem area within the food system where approximately one-third of all food produced gets lost or wasted along the supply chain. Households constitutes one of the largest contributing groups to the global food waste. Reducing food waste at the later stages of the supply chain, including households, is an acknowledged solution to mitigate the negative impacts of the global food system. To reduce food waste, there is a need to have a monitoring system in place since this allows for both an understanding of the current situation as well as a possibility to evaluate the efficacy of food waste-reducing interventions. There are several methods available for quantifying household food waste that each come with their advantages and disadvantages related to e.g. costs, workload and reliability. This study presents a comparison of household food waste quantities when applying different quantification methods. The different methods that are compared are smart bin (where the organic waste bin is placed on a scale that records waste as it occurs), and questionnaire (where the households are asked to estimate their food waste retrospectively) from four households in Uppsala (Sweden) The smart bin data was collected from four households in Uppsala, Sweden, that had been using the smart bins for one year, the questionnaire data were collected from the same households for three weeks. The result from the smart bins and the questionnaire is then compared to national and local statistics collected through waste composition analysis (municipal organic waste is quantified after being sorted and categorised at the waste collecting centre).

The study result shows a significant difference in household food waste quantities between the different quantification methods. On average, the questionnaire registered an average food waste quantity that was 0.85 kg or 57% lower than the average waste recorded by the smart bins during the same period. In a similar manner, the smart bins revealed an average waste that was 43% lower than the national average household food waste quantified by using waste composition analysis. There are several possible factors identified to have influenced the difference in food waste quantities, for instance, demographical factors and errors related to the selected methods. Additionally, the questionnaire method was found to be associated with underreporting and human error when using it for quantifying food waste, giving room for improvements. Instead, the results suggest that the smart bins are to be preferred over questionnaires for quantifying household food waste. However, in order to obtain a more generalisable result a larger sample with a greater demographical spread is required, which can be more costly and require more technical expertise if using smart bins. Further research to develop and apply adequate methodology on household food waste accounting is an essential step in the quest towards reaching a sustainable food system with less food waste.

Keywords: Smart bins, questionnaire, waste composition analysis, sustainable food systems

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1. Introduction

The global food system is faced with many issues related to sustainable development. Expected to have reached almost 10 billion people by 2050 (United Nations 2022), the growth of the global population poses even further challenges to these issues. Production of food is associated with environmental degradation in several ways by contributing to e.g. loss of biodiversity, greenhouse gas emissions and terrestrial and aquatic pollution through the excessive inputs of nitrogen and phosphorus (Springmann et al. 2018). In addition to the environmental aspects there is also the challenge of food security and being able to provide both the current and the future global population with sufficient food (FAO et al. 2020). Taking actions to reduce the burdens which the food system encompasses is therefore a crucial step in the quest towards meeting the goals of sustainable development.

With approximately one-third of all food produced being wasted along the food supply chain (Gustavsson et al. 2011), food waste is a highly relevant and prominent issue to tackle in order to meet the posing challenges of the global food system. Wasting food means that all resources used in previous stages of the supply chain, such as producing, refining, and transporting the food, were used in vain. Consequently, this adds to the multiple impacts the food system has in general with regards to both environmental, economic and social aspects, such as contribution to climate change, higher food costs, and negative impact on food security (Godfray et al. 2010; Vermeulen et al. 2012). The United Nations organ Intergovernmental Panel on Climate Change (IPCC) declares food waste reduction as one opportunity in the strive to reduce global emissions and contribute to the targets stated in the Sustainable Development goals (SDGs) (Mbow et al. 2019). As part of target number 12 in the SDGs, food waste reduction is included, stating that "By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" (United Nations 2017). The retail and consumer levels are currently a major contributor to the global food waste. In the year of 2019, the food waste in this side of the supply chain amounted to 931 million tonnes globally, of which the majority (61%) derived from households (UNEP 2021).

An essential feature in reaching a sustainable food system through the reduction of food waste is the measuring of food waste quantities, something that Caldeira et al.

(2020: 274) presents as “the main challenge toward reducing food waste”. The main argument behind this reasoning is that this kind of data provides the foundation for monitoring and efficiently managing actions taken against food waste and their contribution to global targets (Fanzo et al. 2021). In 2018, the European Union (EU) presented the Directive (EU) 2018/851 Amending Directive 2008/98/EC on Waste. The directive states that all member states should take measures to prevent and reduce food waste in line with the SDGs as well as the targets the Union itself has set of having achieved a 30% and 50% reduction of food waste by 2025 and 2030 respectively (European Commission 2018). The directive also states that member states in this regard should measure food waste in order to track the progress of implemented actions and, to do so, using a common methodology where obtained data should be reported on an annual basis.

As stated by the EU, to obtain relevant and comparable figures, using a common methodology across member states that provides reliable data is an essential feature in the monitoring of food waste quantities. However, there are still many uncertainties regarding generated quantities of food waste. For the household level, which is the largest contributor to food waste, these uncertainties are primarily a result of differences in applied definitions and quantification methodologies (Caldeira et al. 2019). Using self-assessment methods, e.g. questionnaires where households report on food waste quantities from their memory, have shown to result in great underestimations and under-reporting, thus advocating for more objective approaches to obtain more reliable data (Cicatiello & Giordano 2018; Delley & Brunner 2018; Schanes et al. 2018). However, methodologies that are more objective, such as waste composition analysis or direct measurement methods, are usually more resource demanding in terms of cost and time and are therefore usually limited in their implementation regarding e.g. geographical area and number of participants (Xue et al. 2017; CEC 2019; Ammann et al. 2021).

Overall, the most commonly methods used for quantifying household food waste have their strengths and weaknesses related to factors such as time, cost, accuracy and reliability, which in turn influence the results in different ways (Xue et al. 2017). On the one hand, using methods such as questionnaires where people estimate their own waste can be done at lower costs but with the risk of providing unreliable information on food waste quantities (van Herpen et al. 2019b). On the other hand, using more objective methods such as smart bins, where a scale automatically registers wasted quantities, can provide more accurate data but at higher costs due to the technical appliance required (CEC 2019). Therefore, by applying different methods in the same context, it makes it possible to get a deeper understanding on how these methods stand in relation to each other and to what degree the strengths and weaknesses affect the results and what should be taken under consideration when interpreting the results from different studies applying

different methods (van Herpen et al. 2019a). In order to achieve a sustainable food system with less food waste, it is crucial to establish a robust methodology for quantifying household food waste that generates dependable data. This enables effective monitoring and follow-up on the targets established to accomplish the goal set by the United Nations.

1.1 Aim

The aim of this study is to compare household food waste quantifications obtained via smart bins and a questionnaire in four households in Uppsala (Sweden). The outcome of the two quantification methods will be evaluated in relation to each other as well as in relation to Swedish national food waste statistics with the purpose to analyse and discuss similarities and deviations in the observed food waste quantities.

2. Background

The following section provides a background to different methods used to quantify household food waste, including their advantages and disadvantages. Further, different definitions of food waste found in literature are described as well as how food waste can be categorised with regards to its state when discarded. Finally, applied definitions of *household* and *food waste* in the present study are provided.

2.1 Quantification methods of household food waste

Quantifying household food waste can be done in various ways. According to Withanage et al. (2021), there is no optimal method for quantifying household food waste but instead, the choice of method is dependent on the aim and research question of the study as well as resources available. For instance, it is not always necessary to have the most detailed or qualitative information when monitoring the progress of interventions targeting food waste reduction over time while it on the other hand requires a high level of accuracy regarding quantitative information (Quested et al. 2020). Following, methods used to quantify food waste in households and that are relevant to this study are explained more thoroughly.

2.1.1 Direct measurements

Direct measurements mean that food waste is quantified directly as it occurs. The method can vary depending on which level in the supply chain one wants to apply the quantification. For example, electronic scales are often used in manufacturing to weigh the food thrown away, and electronic scanning is often used in retail to scan the food before it gets thrown away. Direct measurements often have high accuracy in their results; however, the method often requires much expertise, is costly, and is time-consuming (CEC 2019). One additional aspect to consider is the potential biases that can occur. Behavioural changes (due to e.g. social desirability or the constant reminder of the participants' food wasting habits, leading to increased consciousness) and sample selection are some of the potential risks that can influence the result (Quested et al. 2020; Withanage et al. 2021).

Kitchen diaries are commonly used when applying direct measurements at the household level (van Herpen et al. 2019b). When using kitchen diaries, the household weighs and records all food that goes to waste over a predetermined number of days. Weighing the food waste on a scale and using grams is the most common approach when using kitchen diaries (van Herpen et al. 2019b). However, the respondent can also be asked to describe the amount of food waste (e.g. half of a tomato) or measure the volume together with why and under which situation the food got wasted (CEC 2019). Kitchen diaries can be filled in online via various documents and apps or by pen and paper. Diaries often record food waste over a more extended period (CEC 2019) which means that they can be time-consuming for the household, resulting in difficulty in recruiting households willing to participate (Withanage et al. 2021). In 2012 Williams et al. quantified household food waste using kitchen diaries in 67 households in county of Värmland (Sweden). The research found an average food waste of 1.7 kg per household per week (Williams et al. 2012). Another study using kitchen diaries to quantify household food waste was performed by Silvennoinen et al. (2014). They found that, on average, a Finnish household wastes 1.2 kg per household per week, resulting in 0.4 kg per capita per week. More recent studies using kitchen diaries for quantifying household food waste have been carried out in Italy and Croatia. These studies showed that, on average, an Italian citizen wastes 0.53 kg per person per week (Giordano et al. 2019) and a Croatian household wastes 3.64 kg per household per week (Ilakovac et al. 2020).

Using a smart bin is another method when applying direct measurements. This method is generally used when measuring food waste in the food service sector (CEC 2019). A smart bin can vary in appearance and technology. However, the basic idea is that the disposal container is connected to a scale that weighs the container as items are added and transmits the information to a database. There are some studies on measuring household food waste with the smart bin method. A recent study by Jones-Garcia et al. (2022) showed that using a smart bin in the household can, in addition to providing information on food waste quantities, also help track eating and wasting behaviour and help the household become more aware of their behaviour. After having implemented the smart bin in 10 households for two weeks, the results showed that the households wasted on average 2.64 kg food per week (Jones-Garcia et al. 2022). Other research has also shown promising results in how smart bins can and help households become more aware of and change their waste behaviour, however, without providing any information regarding how much food is wasted (Thieme et al. 2012; Soma et al. 2020; Guna et al. 2022).

2.1.2 Surveys

Surveys are often efficient and cost-effective for collecting a wide range of information and making rough quantitative estimations about household food waste. Other information that can be collected from surveys is why food waste occurs in the household, attitudes towards food waste, and demographics (CEC 2019). Mostly, surveys are self-administrated, where a questionnaire is sent to the household to be answered, either by paper and pen or through different online survey services. However, surveys can also be researcher administered where the researcher asks the questions (either by phone or in person) and records the answers (Withanage et al. 2021). When the survey is researcher administered, it is less cost-effective than if the survey is self-administered, also researcher administered surveys are often more time consuming because of difficulties to schedule meetings with the participants. Self-administered surveys can, on the other hand, have a low respondent rate (CEC 2019). The self-administration also requires a willingness from people to participate which risks excluding certain societal groups from the study and, thus, influence the representativeness of the sample (Jörissen et al. 2015). Additionally, as for direct measurements, there is a risk for possible biases influencing the results also for studies applying surveys. In today's society, wasting food can be seen as a non-appealing behaviour. Because of this, there is a risk that the participant underreport on their food waste (Withanage et al. 2021).

How the respondent is asked to quantify their food waste and what unit to apply differs between surveys. For instance, Ghinea and Ghiuta (2019) and Schmidt and Matthies (2018) used grams in their surveys. However, it can be difficult for respondents to estimate their household waste in grams; therefore, frequency measures can be used to collect data on how often the household waste food (Parizeau et al. 2015; Setti et al. 2016; Young et al. 2017). Gül et al. (2003) also used the rating categories from definitely wasting to no wasting. Another approach is to use relative or proportional measures where the respondent is asked to report their food waste in the percentage of the portion of all the food that is brought into the household (Stefan et al. 2013; Graham-Rowe et al. 2015; Secondi et al. 2015; Stancu et al. 2016; Aschemann-Witzel et al. 2017). Surveys aiming to quantify household food waste often rely on the participant's memory. Therefore, surveys are not considered a reliable determinant of food waste quantities and often display great underestimations and under-reporting (van Herpen et al. 2019b).

Although not always providing reliable data on food waste quantities or having a main purpose to do so, surveys reporting on how much food households are wasting have been conducted. Jörissen et al. (2015) studied household food waste in Ispra (Italy) and Karlsruhe (Germany) by using online surveys. They found that the average value of edible food waste was 0.13 kg per person per week living in Ispra and 0.14 kg per person per week living in Karlsruhe. Delley and Brunner (2018)

studied avoidable and possibly avoidable household food waste by using self-reported surveys sent out by post to households in Switzerland and found a weekly average of 0.17 kg food waste per capita. Additionally, Van Herpen et al. (2019b) used an online survey to quantify household food waste in the Netherlands and found that a household, on average, wastes 0.64 kg of edible food per week.

2.1.3 Waste composition analysis

A waste composition analysis is a method in which the food waste is directly collected from the household or the recycling centre. The food waste is then, by hand, separated, weighed, and categorised. The categorisation is done to determine if the food was of edible or inedible characteristics when discarded and to see what kind of food gets thrown away (e.g. meat, vegetables, fruit) (CEC 2019). Waste composition analysis does not rely on household self-measurements (as for diaries and surveys) and can be performed independently from the household by a third party, giving that the results are often more accurate and objective. Even though waste composition analysis often is more time-consuming and costly than other methods, it has increased in demand by local authorities and is nowadays usually done more or less regularly (Lebersorger & Schneider 2011).

In 2004 the European Commission suggested a standardised European method for municipalities to preform waste composition analysis on solid waste (European Commission 2004). Despite the attempt, there has not yet been an international standard in methodology. However, in 2019 the European Commission established that member states are obligated to measure and report food waste every full calendar year and recommend using waste composition analysis or direct measurement methods for the household level (Commission Delegated Decision (EU) 2019). The European Commission still advocates establishing a standard methodology for credible and comparable results (European Commission 2018).

In 2005, Waste Sweden (Avfall Sverige), a trade association for Swedish municipalities' waste management, developed manuals, checklists and guidance for Swedish municipalities to perform and analyse waste compositions. This material has since been updated and expanded, most recently in 2021. Suppose the municipality follows the guidance provided by Waste Sweden when performing waste composition analysis. In that case, they are allowed to register their result on Waste Web (Avfall Web). Waste Web is a statistical tool for all the Swedish municipalities to benchmark, and compare their waste composition analysis results with all the other municipalities in Sweden (Avfall Sverige 2022b). Waste Sweden annually compiles the data in Waste Web to the national food waste statistic and delivers a statistical base to the Swedish Energy Agency, the Swedish

Environmental Protection Agency and Statistics Sweden, among others (Avfall Sverige 2022a).

Primarily based on the waste compositional data provided by Waste Sweden, the Swedish Environmental Protection Agency (SEPA) estimates that the food waste generated within Swedish households amounted to approximately 61 kilograms of solid food (including both edible and non-edible parts) per person per in 2020, which corresponds to 1.2 kg per person per week (Hultén et al. 2022). Using a similar approach as in Sweden, waste compositional from the United Kingdom (UK) revealed that UK households in 2012 wasted, on average, 3.5 kg of solid food per week (Quested et al. 2013). Further, Parizeau et al. (2015) found through a study where they quantified households' organic waste collected by the municipality that Canadian households generated on average 4.2 kg of organic waste per week. Another study that quantified household food waste in Switzerland by using extrapolation from a waste composition analysis (in addition to conducting a self-reporting survey) found a food waste level of 1.7 kg per person per week (Delley & Brunner 2018). However, the Swiss study only considered what the writers referred to as edible (avoidable and possibly avoidable) food whereas the reported waste from Sweden and the UK refers to both edible and inedible food.

2.2 Food waste definitions

The monitoring of food waste is an essential aspect in the strive towards a sustainable food system since this provides information on what actions and interventions should be prioritised, where they should be targeted as well as to their efficacy (Lebersorger & Schneider 2011; Xue et al. 2017; Withanage et al. 2021). However, in order to compare quantities and performances between different interventions and between countries, a united foundation to what food waste refers to is required since this factor significantly influences the outputs and consequently the monitoring of generated quantities (Caldeira et al. 2019).

There is no single definition of the term *food waste* or what it should infer. In the earlier stages of the food supply chain, before entering the retail and consumer stages, food that was intended for human consumption but for any reason has been removed or discarded is usually described as food *loss* rather than food *waste* (FAO 2013; UNEP 2021). Food *waste* is instead commonly associated with the wastage of food in the later stages of the food supply chain, including e.g., retail, manufacturing and households. Perspectives on what type of food and associated parts should be considered as waste differs between existing definitions, where a few more acknowledged ones have been suggested by the Food and Agriculture

Organization of the United Nations (FAO), the FUSIONS project by the European Union, and the United Nations' Environment Programme (UNEP) respectively.

FAO's suggested definition of food waste refers to discarding food that is, or at some point was, suitable for human consumption (FAO 2013). To make this definition more precise, Östergren et al. (2014) stated as part of the FUSIONS project that food waste includes all food and inedible parts of food that does not reach the intended human consumption, where they consider the whole food supply chain from food being ready for harvest to food being prepared for consumption. To make the term even more specific, UNEP (2021) specifies that food waste refers to food and any associated part that is removed from the human food supply chain in the stages including retail, food service and households. UNEP (2021) also defines food itself as "Any substance – whether processed, semi-processed or raw – that is intended for human consumption" (UNEP 2021:19), which includes drinks and food that no longer is suitable for human consumption but excludes drugs, tobacco and cosmetic products.

2.2.1 Edible and inedible food waste

Food waste can further be divided in subcategories based on its characteristics which allows for a deeper understanding of what kind of food is wasted and what kind of actions could be taken to reduce the waste. Commonly, these categories rely on the separation between *edible* and *inedible* food or *avoidable* and *unavoidable* food waste (Schneider 2013). As for food waste, there is no single acknowledged definition of the different terms. What is defined as inedible and edible food can vary widely between countries, regions, and consumer preferences. For example, chicken feet are prepared and consumed in Asia while in many European countries, chicken feet are classified as inedible food. On the consumer preference level, some consumers consider different peels as edible, while others consider the same peels as inedible (Teigiserova et al. 2020). The distinguishment between edible and inedible food waste and what should be included in each of these categories varies between studies and is one of the reasons to uncertainties and discrepancies in food waste statistics (Caldeira et al. 2019).

To mitigate the influence of the categorisation of edibility in studies on food waste, Nicholes et al. (2019) proposed a methodology to identify what food and parts of food the general population consider belong to each category. This also allows for accounting for factors related to culture, however they do acknowledge that some dissensions are ultimately inevitable when making these types of classifications. The method infers an objective classification of what is considered as edible and inedible across a larger population which is obtained by using a questionnaire. The questionnaire asks the respondents about their perception of different food parts

which are commonly found in the country and which the authors find to be difficult to classify as edible or inedible. Based on the respondents' answers on their perception of edibility of each item and how often they claim to consume the items themselves, an 'edibility score' can be attributed each item where a score ≥0.5 gives that the item would be considered as possibly avoidable (possibly edible) and anything below that would be considered as unavoidable (inedible).

Making the distinguishment between edible and inedible parts when quantifying food waste has both its advantages and disadvantages. On the one hand, it allows for measures to be targeted more specifically for each separate flow. On the other hand it constrains the practicalities of implementing a common accounting methodology between different countries (Tostivint et al. 2016). In literature, there are some suggestions to what inedible food waste should refer to. For instance, inedible food waste has been defined by the Food Loss and Waste Protocol as: "Components associated with a food that, in a particular food supply chain, are not intended to be consumed by humans. Examples of inedible parts associated with food could include bones, rinds, and pits/stones."(Food Loss and Waste Protocol 2023). In addition to this, Tavill (2020) also recognises that the classification of inedibility may differ between consumers and therefore states that inedible food "… also include parts that may be edible or inedible based on social, cultural or other preferences, such as apple peels, carrot tops, cucumber seeds, etc".

2.3 Applied definitions

To determine quantities of food waste, the term *food waste* needs to be defined. This study refers to food waste as any food and part of food that was discarded in the households' organic waste bins regardless of its state and edibility characteristics. This definition is based on the smart bins not considering what is thrown away in any other bin or down the drain, and the quantitative registration does not distinguish between edible and non-edible food. Additionally, the definition of food waste applied in this study allows for comparison to the national statistics of Sweden reported by SEPA. The statistics on household food waste in Sweden is presented both as divided between avoidable and unavoidable food waste and as the two fractions together (Hultén et al. 2022). SEPA also reports food and drinks poured down the drain as their own fraction and can therefore be separated from solid household food waste which is the focus of the present study. This way of reporting the national statistics therefore makes it possible to upscale the results from the present study and put them in comparison with the ones reported by SEPA.

Besides the necessity of defining the term food waste, for this study there is also a need to define what *household* refers to. In this study, the meaning of household is

primarily based on the practicalities of the selected quantification methods. In the Swedish encyclopaedia, the word household is described as “group of people with a shared home and shared consumption of daily goods often family but also larger and smaller groups respectively (or one single person)” (Swedish National Encyklopedia n.d.). However, since neither the smart bins nor the composition analysis distinguishes between if there are only the people registered at the address of the household, i.e. sharing the home, that contributes to the waste or if there are other people (e.g. dinner guests) also contributing, this study does not specify who is wasting the food or whether they are part of the actual household or not. Additionally, since the food waste can only be monitored by the smart bins if the food is wasted in the organic waste bin in the household, wastage occurring outside of the home is not included nor is any food or drinks poured down the drain or in any other bin. Thus, household food waste in this study refers to all food waste generated within homes, regardless of who is wasting the food, and that is thrown in the organic waste bin.

3. Material and methods

This study compared three methods that quantifies household food waste. For two of the methods, the basis for the comparison were based on quantification data from households in Uppsala, Sweden, while the third method was based on national food waste data. The research was comprised by four steps which are illustrated in Figure 1.

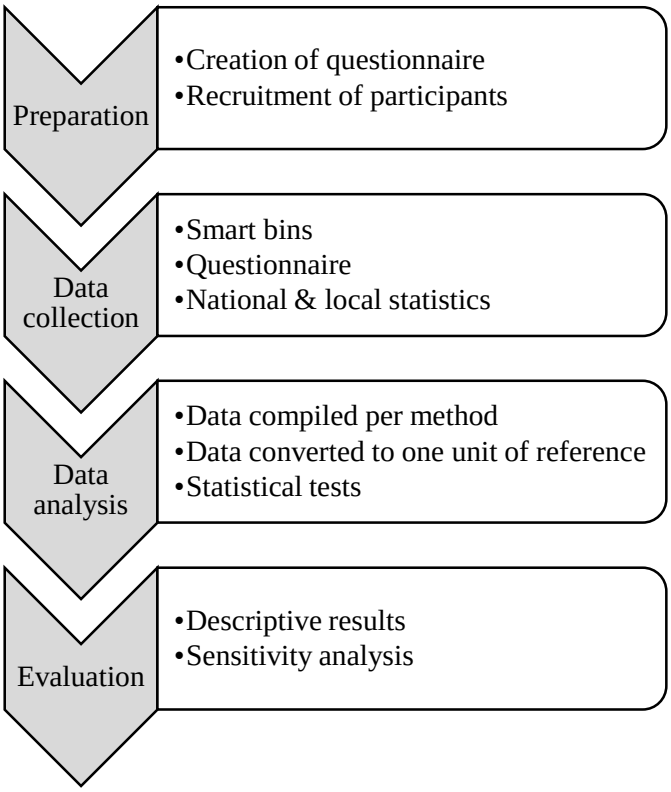

Figure 1. Schematic illustration of steps performed to conduct the study.

3.1 Preparation and data collection

Data was collected during different time periods. Figure 2 illustrates a timeline from when data from all quantification methods was collected.

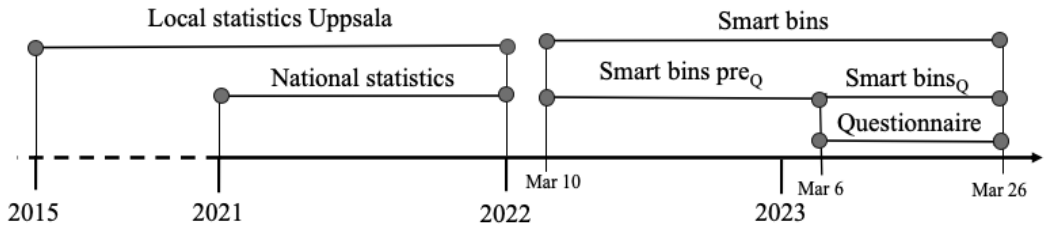

Figure 2. Timeline illustrating periods from when data used in the study was collected.

3.1.1 Smart bins

Quantification data on household food waste was gathered from four households in Uppsala, Sweden, that had been using smart bins for one to two years prior to the present study (see Table 1). The smart bin consists of a scale, on which the bin for organic waste is placed, and a camera placed above it. Every time something is placed in the bin, the scale registers the weight of the item(s), and the camera is triggered to take a photo. The idea is that the taken photo can be compared to the previous image in order to tell which type of food was thrown away, which is so far done manually and was not included in the scope of the present study. Figure 3 pictures a prototype and a camera view of one of the smart bins installed in the households.

Figure 3. Example of the smart bin prototype and camera view from one of the four households.

The households using the smart bins were part of a pilot study conducted by researchers at The Swedish University of Agricultural Sciences (SLU) in Uppsala. The main purpose of the pilot study was to test how food waste quantification can

be made in households using smart bins and to get insight to the method before attempting to conduct studies on a larger scale. The households where these quantifications had taken place were selected based on a convenience sampling approach where the participants were involved in the development and testing of the smart bins. Demographics on the participating households are presented in Table 1.

Table 1. Demographic description of participating households using the smart bin and conducting the survey.

Household	Household members (of which children under age 18)	Accommodation	First registration with smart bin
1	1	Apartment	2022-03-10
2	3 (1)	Apartment	2022-01-19
3	2	Apartment	2021-05-04
4	5 (3)	Apartment	2021-09-27

3.1.2 Household food waste questionnaire

For the survey method, a questionnaire based on the method described by van Herpen et al. (2019a) was created and distributed to the four households where the smart bins had been implemented which allowed for a comparison between the different food waste quantification methods. The Household Food Waste Questionnaire was designed to address shortcomings of other survey methods by increasing the participants' awareness on food waste, limiting the timeframe of implementation and by denoting product categories in a more detailed manner (van Herpen et al. 2019a). The basic idea is that the respondent is made aware on beforehand that they will be asked to fill out a questionnaire with regards to what they have wasted during a predefined period. When filling out the questionnaire retrospectively, the respondent first selects which categories of food were wasted during the defined period which is followed by questions regarding the amount of waste and its state for each selected category. However, in the present study, the original suggested method of The Household Food Waste Questionnaire had to be slightly modified in order to meet the aim of the study and to fit into the definitions applied in the study.

First, the method suggested by van Herpen et al. (2019a) includes only edible fractions of food products and does not distinguish between destinations where the food waste ends up, i.e. if it is thrown away in the organic waste bin, the sewer or the residual waste bin. Since the quantities reported through the questionnaire were to be compared to those registered by the smart bins, the inclusion criteria on what should be measured needed to be the same. This required the questionnaire in this study to include all food (and possible non-food) products thrown in the organic waste bin to be accounted for and excluding drinks and food thrown in any other

bin or down the drain. The inclusion of inedible food parts further required adjustments to be made in the listed food categories where the categories ‘coffee grounds and tea leaves/bags’, ‘non-food products’ and ‘other (non-listed foods, edible or inedible parts or any other products thrown in the organic waste bin)’ were added. In addition to this, in the follow up questions to the listed food categories a fifth option was added to the categorisation of the foods, namely ‘inedible parts’. For similar reasons, categories referring to drinks or liquids, such as beverages of any kind and sauces, were removed from the list. A copy of the distributed questionnaire is presented in Appendix 1.

The questionnaire was created in the online survey tool Netigate. The defined period for each questionnaire was set to one week. Three days prior to the start of the survey period, a pre-announcement was sent out by e-mail to the participants where they were informed on the start and finish dates of the survey, what was expected from them and the structure of the forthcoming survey. Seven days after the start date, each participant was sent another e-mail that provided them with a link to the survey which they were asked to fill in within 48 hours (the survey was however still available after this period if anyone for some reason did not fill it in during the 48 hours). Each participant was provided with a unique link so that answers could be separated from each other. This procedure was repeated four times, resulting in data covering four weeks for each of the four households. However, the first week was not included in the final analysis, but instead regarded as a pilot study to test the modified questionnaire in order to validate the added categories and questions in the slightly modified version. After the first week, the participants were therefore asked to provide any feedback regarding the questionnaire. This led to some clarifying information being added to some of the questions regarding the categorisation of amounts in relation to inedible parts, such as (approximately) how much potato peel is equivalent to one medium sized potato.

3.1.3 National and local statistics

Food waste quantities from the waste composition analysis were obtained from the work carried out by Swedish municipalities that was reported to Waste Sweden. After being contacted, Waste Sweden provided access to their internal web, Waste Web. Data for the national statistics on household food waste was then downloaded from Waste Web and compiled in an Excel spreadsheet. Data for the local statistics from Uppsala was collected through the municipality’s own company, Uppsala water & waste (Uppsala Vatten), which provided detailed geographic information on the areas from where the data had been collected from.

3.2 Data analysis

The following section describes the process of analysing the quantification data collected through the smart bins, questionnaire, and waste composition analysis. An explanation of how the data obtained from the different methods was made comparable is also provided along with how the results were upscaled to be set in relation to official Swedish numbers.

3.2.1 Smart bins

Quantification data registered by the smart bins was collected and summarised as waste per household per week. Since the four households had started using the smart bin at different times, the data for all households was taken from the time when the last household started using the smart bin. This gave that the analysis on total food waste registered by the smart bins was based on data collected between 2022-03-10 and 2023-03-26. However, during this period, food waste was not registered continuously by all households. Therefore, the analysis includes only weeks when food waste was registered (a total of 159 weeks) and the conversion to the reference unit was based on total amount of recorded food waste and the total number of weeks where food waste was registered by each household.

Additionally, during the period when the questionnaire was running (2023-03-06 – 2023-03-26), the smart bins were continuously collecting information on the food waste in the four households. The quantification data collected during this period by the smart bins (henceforth referred to as smart bins$_Q$) was used to compare against the questionnaire. In accordance with the set period for the questionnaire, data from the smart bins$_Q$ was compiled on a weekly basis for the purpose of comparing the results from the two methods. All data from the smart bins was retrieved from the database that stored this information after the finalisation of the last week of collecting data through the questionnaire and then divided per period (i.e., smart bins, smart bins$_Q$ and smart bins pre$_Q$ as illustrated in Figure 2.

3.2.2 Questionnaire

Similar to the quantification data obtained from the smart bins, the food waste quantities reported through the questionnaire were summarised per household per week. Since the questionnaire asked for wasted amounts in relative figures (e.g., serving spoons), the answers needed to be converted into absolute amounts, i.e., grams. To do so, calculating the sum of reported waste for each category in relative amounts used the average corresponding absolute amount suggested by van Herpen et al. (2019a) in their Appendix F. However, in three of the categories listed in the questionnaire (*fresh fruits*, *fish* and *eggs*), the sum of waste for the category was considered to be significantly influenced by the character of the waste (i.e. if it was

considered inedible or not). Values of inedible fractions were therefore added to the list of those categories and used to correct the sum of waste for each category if *inedible parts* were selected in the follow up question for the specific category. For the estimation of inedible fractions of fresh fruits, an average value of 21% for inedible fractions was taken based on an average value from a list presented by Ruiz-Torralba et al. (2018). Similarly for the inedible fraction of eggs (i.e. egg shells), a value was taken from Travel et al. (2011) which suggested that the average fraction of a whole egg consisting of the shell is 10%. For the category *fish*, an estimated value of inedible parts (skin and bones) was set to 10%. In the calculations, if any additional option along with inedible parts was selected in the follow up question (e.g. partly used food), the share of inedible and edible parts respectively was corrected to the share of options selected, meaning if two more options were selected the share of inedible parts was assumed to account for one third of the total waste for that category. The questionnaire responses were summarised after each week and compiled by household and week as well as a total. This allowed for the recordings of food waste collected through the questionnaire to be compared against those recordings collected by the smart bins$_Q$ during the same period both in its total and on a more detailed level (per each specific household and week).

3.2.3 National and local statistics

For the national statistics, the data for analysis on waste composition was taken from 2021 since this was the most recent year with sufficient amount of data where 256 out of 290 municipalities had reported their food waste as a separate category. The deadline for the municipalities to report to Waste Sweden on data from the year 2022 had not passed at the time when the data was downloaded, thus for 2022 only 38 municipalities had reported data on household food waste that far. Reporting data to Waste Sweden requires a coherence in applied methodology between municipalities on how data is collected. Consequently, municipalities without food waste registered as a separate category in the data set from Waste Sweden were excluded from the analysis. Additionally, Waste Sweden reported their statistics as total food waste per year as well as providing the number of inhabitants in each municipality, thus using a different reference unit than the one applied in the present study (waste per household per week) which needed to be corrected for being able to compare the methods.

3.2.4 Reference unit

To be able to compare the results of the different methods, a coherent unit of reference was needed. This unit was set to *kg food waste per household per week*. All calculations were therefore based on compiling the total amount of registered

food waste per method and dividing them by the number of households having registered food waste and the number of weeks they had been registered. To convert the quantification data presented in the national statistics to the established reference unit, a factor of 2.20 was applied to the calculations of average food waste per household as this was the value suggested by Statistics Sweden on the national average number of inhabitants per household (Statistics Sweden 2022).

For the local data for Uppsala Municipality, food waste fractions had been collected and analysed from three different areas, constituted by different accommodation constellations. Since all four households who used the smart bins and responded to the questionnaire were accommodated in apartments, the local statistics used to compare against were the ones with data collected from apartments in a similar urban area. However, when only considering households living in apartment buildings, the average household consists of only 1.86 people (as opposed to the national average of 2.20) (Statistics Sweden 2022) which therefore was used to calculate the average waste for households living in apartment buildings in Uppsala Municipality. Annual data for the entire municipality was available from the year 2015 until 2022. Data specifying areas in Uppsala where food waste had been collected was however only available from two of these years, 2018 and 2022, which therefore were the years providing the basis for average food waste amounts from apartments.

3.2.5 Sensitivity analysis and upscaling

The values used to calculate the waste reported through the questionnaire were based on average quantities as suggested by van Herpen et al. (2019a). However, this approach infers a potential risk for misguidance since the gaps between answers options may differ up to tenfold (see e.g. answer options in the bread category in Appendix 2 where answer option 1 assumes an average weight of 18 g, option 2 assumes 35 g and option 3 assumes 400 g). Therefore, a sensitivity analysis was performed to see how the assumed value for each answer option could influence the results. Applied minimum, average, and maximum values used to calculate the waste reported through the questionnaire are presented in Appendix 2. To obtain the range for each answer option, the suggested values of the two options following each other (e.g. the values of answer options 1 and 2) were added together and then divided by two where the quotient was used as the maximum value for the first listed answer option out of the two (in the example above that would be the maximum value in the range for answer option 1). The minimum value for answer option one was assumed to be 1 g since that is the least possible amount of waste to possibly generate using the same number of significant figures as van Herpen et al. (2019a). The minimum value for the remaining answer options was adopted to be 1 g more than the maximum value for the previous answer option. For the

answer “more than X units” the applied value was assumed to be one plus unit (e.g., “more than five eggs” was assumed to be six eggs).

For upscaling the obtained values from the present study to a national level, the Swedish national average figure of solid food waste per person reported by SEPA (61 kg per person and year) was used compare against. To make results from the smart bins, questionnaire and Waste Sweden comparable to those reported by SEPA, they were converted to the same unit as applied by SEPA, i.e., kg food waste per capita per year, by dividing the waste per household with the number of average household size and multiplying that with the number of weeks there are in one year.

3.2.6 Statistical tests

To illustrate a point estimate of a result (e.g. a mean value), a confidence interval can be applied which provides a range in which the mean of the whole population can be found with a certain degree of confidence, e.g. 95% (O’Brien & Yi 2016). A confidence interval with a 95% degree of confidence was applied to the calculated average waste for all groups of quantification methods to visualise if a significant difference in registered food waste quantities could be assumed between the methods. For groups where a difference could not be visually assumed between them, the confidence interval was complimented by conducting a two-sampled t-test (α=0.05) with assumed equal variance for each paired combination of methods using the function in Microsoft Excel (version 16.71).

4. Results

The questionnaire result indicates that, on average, the amount of food waste reported was 0.85 kg or 57% lower than the quantity registered by the smart bins$_Q$. Additionally, regarding the smart bins$_Q$ and questionnaire, in all cases the participants reported a lower quantity of food waste in the questionnaire than what was recorded by the smart bins$_Q$. The quantities of recorded food waste from each household and week, using both the smart bins$_Q$ and the questionnaire, are presented in Table 2.

Table 2. Results on household food waste quantities provided by smart bins$_Q$ and questionnaire respectively. Difference in registered quantities between the methods are displayed as both mass and percentage where the questionnaire is set in relation to the smart bins$_Q$.

	Waste (kg)		**Difference**	
	Smart bins$_Q$	**Questionnaire**	**kg**	**%**
Household 1				
Week 1	0.26	0.14	0.12	- 46
Week 2	0.19	0.16	0.03	- 16
Week 3	0.28	0.21	0.07	- 25
Average	**0.24**	**0.17**	**0.08**	**- 33**
Household 2				
Week 1	2.83	0.75	2.08	- 73
Week 2	2.44	0.90	1.54	- 63
Week 3	2.22	0.73	1.49	- 67
Average	**2.50**	**0.79**	**1.71**	**- 68**
Household 3				
Week 1	0.90	0.42	0.48	- 53
Week 2	0.72	0.16	0.56	- 78
Week 3	0.85	0.23	0.62	- 73
Average	**0.82**	**0.27**	**0.55**	**- 67**
Household 4				
Week 1	2.55	1.96	0.59	- 23
Week 2	2.05	0.76	1.29	- 63
Week 3	2.51	1.12	1.39	- 55
Average	**2.37**	**1.28**	**1.09**	**- 46**

The result showed that the participants reported their food waste through the questionnaire to be, on average, 0.63 (± 0.31) kg per week. Based on the same period as when data was collected through the questionnaire, the smart $bins_Q$ showed that the households wasted, on average, 1.48 (± 0.58) kg per week. The total quantified food waste from the smart bins showed that the households, on average, wasted 1.12 (± 0.18) kg food per week. Additionally, the national statistics, collected through waste composition analysis, showed that the average food waste was 1.95 (± 0.09) kg per household per week. On a local level, households in Uppsala wasted on average 1.90 (± 0.05) kg per household per week. When considering only apartment accommodations in Uppsala, the corresponding average was 0.58 (± 0.29) kg of food waste per household per week. In Figure 4 the results are illustrated with a 95% confidence interval.

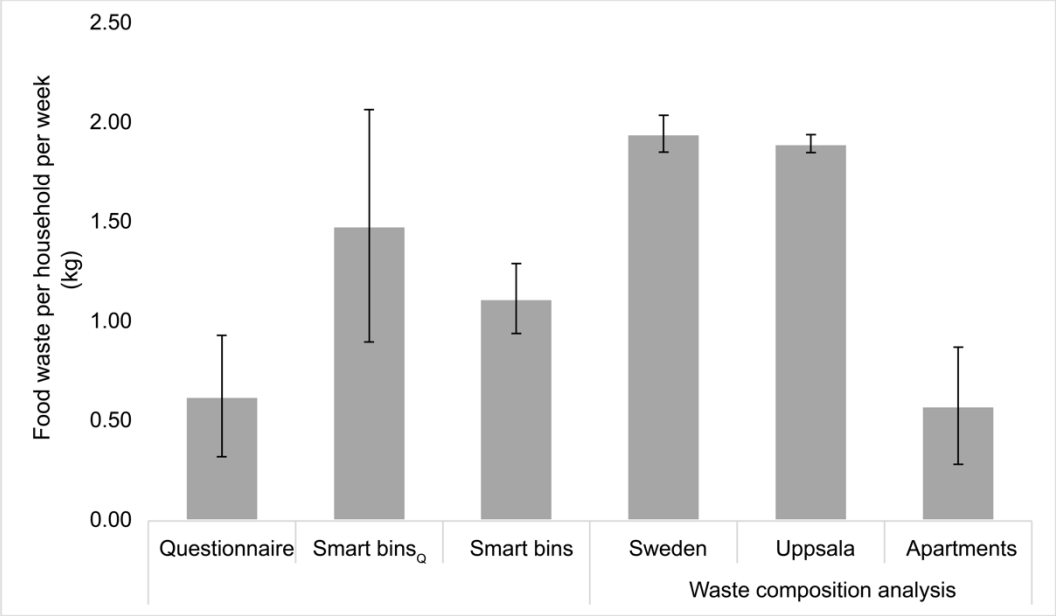

Figure 4. Average weekly food waste quantities registered by different methods and periods (Questionnaire and Smart $bins_Q$: 2023-03-06 to 2023-03-26; Sweden: 2021; Uppsala 2015-2022; Apartments (Uppsala): 2018 and 2022) applying a 95% confidence interval.

Comparing all the data illustrated in Figure 4, the confidence interval of 95% indicated that a significant difference could not be assumed between questionnaire and smart $bins_Q$, questionnaire and smart bins, as well as smart bins and apartments in Uppsala. Table 3 shows that the t-test results indicate a significant difference between the questionnaire and smart $bins_Q$ as well as between the questionnaire and smart bins. However, no significant difference was observed between the smart bins and apartments in Uppsala.

Table 3. t-test performed on variables where a difference could not be assumed from the confidence interval displayed in Figure 1. α =0.05.

Variable 1	Variable 2	p-value
Questionnaire	Smart bins$_Q$	0.018
Questionnaire	Smart bins	0.019
Smart bins	Apartments	0.256

Comparing the total average recorded food waste from the three smart bin periods in relation to each other, see Figure 5, the result showed no significant difference between the tree periods. When comparing the results per household, the waste registered during the smart bins$_Q$ period stood out from the prior period (smart bins pre$_Q$) and from the total smart bin period while the waste levels for the other three household revealed no differences between the periods.

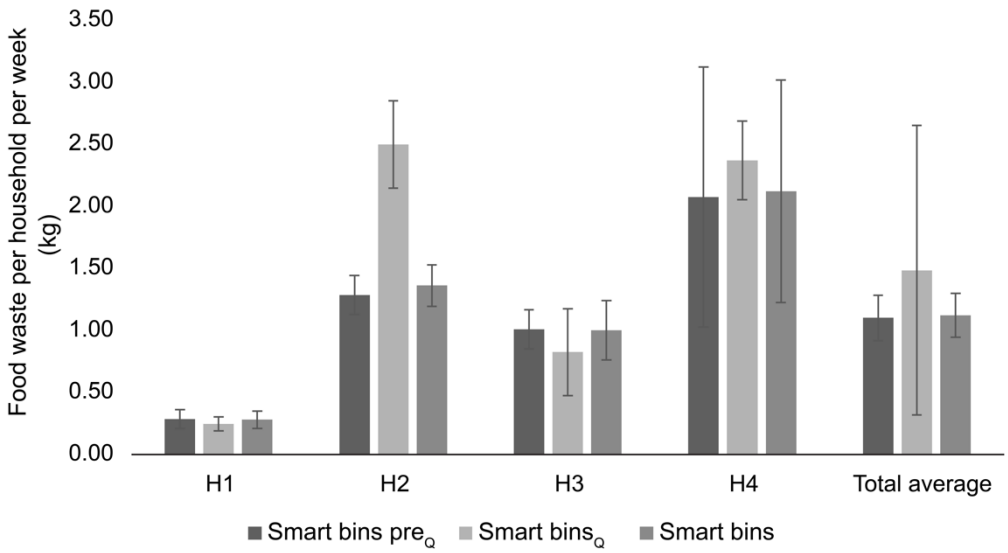

Figure 5. Average weekly food waste quantities registered by the smart bins in each of the participating households during a year prior to the questionnaire period (from 2022-03-10 to 2023-02-26) and during the questionnaire period (2023-03-06 to 2023-03-26) and these periods together (Smart bins) applying a 95% confidence interval.

4.1 Sensitivity analysis and upscaling

Table 4 provides an overview to how the average, minimum and maximum values in the questionnaire correlate to the result from the smart bins$_Q$. Assuming the maximum value in the possible range for each answer in the questionnaire, twelve weeks reported a higher value of weekly food waste than recorded by the smart bins$_Q$. The total reported food waste using the maximum value was found to be 40%

lower than the waste registered by the smart bins$_Q$ (compared to 57% when assuming the average value). Four of the total On the other hand, assuming the minimum value in the possible range for each answer in the questionnaire, the total reported food waste resulted in an even greater difference in relation to the smart bins$_Q$ (70%).

Table 4. Registered weekly food waste quantities per household using smart bins and different assumed weights corresponding to the relative amounts reported by the questionnaire. Values marked with yellow: maximum assumed weight from questionnaire > weight registered by smart bin.

Household	**Questionnaire**			**Smart bins$_Q$**
(week)	**Average (kg)**	**Min (kg)**	**Max (kg)**	**(kg)**
1 (1)	0.14	0.09	0.20	0.26
1 (2)	0.16	0.09	0.26	0.19
1 (3)	0.21	0.14	0.30	0.28
2 (1)	0.75	0.49	1.07	2.83
2 (2)	0.90	0.64	1.18	2.44
2 (3)	0.73	0.50	1.01	2.22
3 (1)	0.42	0.29	0.74	0.90
3 (2)	0.16	0.05	0.31	0.72
3 (3)	0.23	0.14	0.35	0.85
4 (1)	1.96	1.53	2.74	2.55
4 (2)	0.76	0.56	1.01	2.05
4 (3)	1.12	0.81	1.53	2.51
Total	**7.54**	**5.39**	**10.86**	**17.81**

When comparing the results from the smart bins, questionnaire, and national average obtained from waste composition analysis to the official number provided by SEPA, the latter reported a greater yearly food waste per person than all three methods investigated in the present study (Table 5).

Table 5. Comparison between results from present study and official Swedish numbers presented by the Swedish Environmental Protection Agency (SEPA).

Source	**Waste per person per year (kg)**	**Difference from SEPA (%)**
SEPA	61.00	
Smart bins	21.24	- 65
Questionnaire	11.95	- 80
Waste Sweden	46.22	- 24

5. Discussion

Using the questionnaire, the households reported to waste on average 0.63 (± 0.31) kg food per week, which is 57% lower than the average waste recorded by the smart bins during the same period (1.48 (± 0.58) kg per week). Additionally, the national statistics, based on waste composition analysis, showed that Swedish households waste on average 1.95 (± 0.09) kg food per week. This suggests that the four households waste on average 43% less food per household than the national average according to the smart bins. Comparing all three methods, the smart bins and the questionnaire, both reported lower levels of weekly household food waste than the national data collected through waste compositional analysis with the questionnaire reporting the lowest. However, when considering only apartments on a local level in Uppsala, the average food waste reported was only 0.58 (± 0.29) kg per household per week, which is even lower than the waste reported through the questionnaire. Factors that might have influenced these results are discussed further below, along with limitations and suggestions to further research in the subject.

5.1 Differences in quantities of household food waste

The result indicated a difference in recorded household food waste depending on quantification method (see Figure 4). In this study, a main purpose was to compare a survey method and a method using a direct measurement against each other. With regards to this purpose, smart bins were chosen as the direct measurement method, whereas the Household Food Waste Questionnaire was chosen to represent a survey method. However, when using different quantification methods simountaneusley there is a possible risk for the methods to influence each others' result (van Herpen et al. 2019a). The week before the questionnaire period started, a pre-announcement was sent to the participants with the purpose of making the participants aware of the waste that was thrown in the organic waste bin. The pre-announcement could have affected the participants in both wasting less food in general and/or throwing less food in the organic waste bin. However, when comparing the data from smart bins pre_Q, smart $bins_Q$, and smart bins, there is no indication of any difference in recorded food waste quantities between the periods. The absence of difference may be a result of the fact that the participants already had been quantifying their food

waste for one plus year prior to when the present study was conducted. This could potentially mean that any behavioural changes have been naturalised or became common practice before the initiation of the questionnaire. Moreover, the mere activity of quantifying food waste could potentially be considered as a measure to reduce food waste itself since it brings light to the issue and can make participants more aware of their behaviour (Eriksson et al. 2019). This could also be a possible explaination to why the participants having used the smart bins for over a year revealed a weekly average food waste lower than the average household on a national level.

Although direct measurements have shown to provide more accurate information on household food waste than survey methods (van Herpen et al. 2019a), surveys are still commonly used for obtaining data on food waste amounts. When validating their method of the Household Food Waste Questionnaire, van Herpen et al. (2019a) found that, compared to waste reported through diaries (i.e. a direct measurement method), the waste reported through the questionnaire was on average 43% lower. This difference between the two quantification methods found by van Herpen et al. (2019a) were similar to the ones found in the present study, where, however, the latter found an even greater difference between the methods. The greater discrepancy found between the methods in the present study could for instance be a result of differences in household constellations or the adjustments made to the questionnaire. Also, using diaries to quantify household food waste infers a risk of potential bias or intentional underreporting similar to questionnaire methodologies. On the other hand, using a technical solution like the smart bins infers a potential risk of technical errors which also infers a risk of influencing the results. This could be another explanation to why the difference between the questionnaire and the compared direct measurement method is greater in the present study than what was found by van Herpen et al. (2019a).

According to the results of the present study, the questionnaire reported an average food waste amount that was 57% lower than the waste registered by the smart bins$_Q$. A possible explanation for this result could be that the questionnaire depends on the participants' memory of what has been thrown in the organic waste bin (van Herpen et al. 2019b). Another possible explanation for the underreporting is that, as Withanage et al. (2021) mention, food wastage can be seen as a non-appealing behaviour and can therefore be a cause for participants to consciously underreport on their food waste. Nonetheless, regardless whether it is the participants' memory or a desire to have an appealing behaviour that can be a cause to underreporting, using methods like the questionnaire infers a risk for it to be affected by human bias/error. Additionally, as seen in the results, the method may not be considered as valid for quantifying food waste, at least in its current format. Instead, using the method of surveys, the aim most commonly is to identify and understand the root

cause of why households waste food which could be a way of applying the Household Food Waste Questionnaire in the future. Some of the causes that have been found to affect household food waste in previous studies investigating reasons behind household food waste are shopping and eating behaviours, special offers in the store (e.g. buy two for the price of one), and scepticism towards eating food that passed the "best before" date (Schmidt & Matthies 2018; Ghinea & Ghiuta 2019). These are factors that have been found to explain household food waste through using survey methods. If extending the present study to analyse reasons behind food waste, they could for instance be seen as possible factors that explain why Household 2 has a significantly higher average food waste quantity registered by smart $bins_Q$ compared to the smart bins pre_Q and smart bins periods.

The identification of undereporting in the questionnaire suggests a degree of uncertainty associated with this particular method. Compared to the smart $bins_Q$, the questionnaire was found to underreport on generated food waste quantities by, on average, 57%. Since the data reported through the smart $bins_Q$ and the questionnaire originates from the same waste, the difference in registered quantities between those two methods can be determined to lie in methodological factors. Additionally, comparing the smart bins against the national statistics, the weekly average food waste per household recorded by the smart bins was 43% lower than the national average. As opposed to the divergence between the smart $bins_Q$ and the questionnaire, this difference can not be seen as an indication to any uncertainties between the methods since the data behind the results did not derrive from the same households. It can also not be concluded that methodological factors alone may have influenced the difference result as factors such as demographical ones becomes relevant in this matter.

The households using the smart bins were most likely not a representative sample of the whole population which therefore makes it difficult to compare the results from smart bins and national statistics against each other. However, taking the case of the locally collected data that was gathered from an area with an accommodation type similar to the ones the households using the smart bins live in, the results showed that the average waste was higher for the households using the smart bin. The average reported amount of food waste deriving from an area in Uppsala constituting of only apartments (0.58 (± 0.29) kg of food waste per household per week) was significantly lower from the municipal average (1.90 (± 0.05) kg per household per week). Considering that the Uppsala average, including different types of accommodations and areas, was more than three times as high as the average waste deriving from apartments, and that the municipal average was based on data from eight years while the data specifying areas only from two, the reported waste from apartments in Uppsala should however be interpreted with care. Also, since the geographically specified local data only was available from two years this

result is associated with a some uncertainty and, as delineated by the t-test, an actual difference between this data and the smart bins could not be assumed. Despite this, the local data can be seen as providing an indicator to that households similar to the ones using the smart bins are not a representative sample of the population. It is also plausible that their recorded food waste is lower than the national waste composition analysis data.

Besides the demographical factors, there can also have been administrative factors related to how data was treated that influenced the results. One such administrative factor that relates to the difference between the smart bins and questionnaire results and the national statistics is the chosen unit of reference. What should be noted regarding this aspect is that the average household size used to calculate the average waste differs between the smart bins/questionnaires and the national/local statistics. For the smart bins and the questionnaire, the average household size is based on the actual members in the participating households (i.e. an average of 2.75 members per household), whereas for the local and national statistics, the average household size was not known and therefore based on a national average (2.2). This difference means that, if presented as food waste per person instead of per household, the average discrepancy between the smart bins and the national statistics would be even greater, 54% instead of 43%. On the other hand, if comparing the smart bins and local statistics from apartments and using waste per person as the reference unit, the results from the methods become more coherent than previously presented. The smart bins recorded an average waste per person and week of 0.41 kg while the local data suggested that the geographically similar accommodation type waste on average 0.31 kg per person per week, a 25% difference instead of 48% as previously suggested. These differences provide an indicatation to how the chosen reference unit may influence the result and that this factor should be taken under consideration before generalising or drawing any conclusions on data presented as ‘food waste per household’.

Furthermore, in a previous study from the UK that also was applying smart bins to quantify household food waste, the importance of understanding the average household size when using ‘household’ as reference unit becomes even more evident. The study revealed that the participating households wasted on average 2.64 kg food per week (Jones-Garcia et al. 2022), which is more than the average waste observed by all methods investigated in the present study. However, the average household size in the UK study was 3.1 members per household, meaning that if adjusted to waste per *person* per week, the average weight would be 0.85 kg. This can be considered slightly more equivalent with the result from the smart bins in the present study (0.41 kg per person per week), where the difference from the adjusted units would result in a 52% lower value for the smart bins rather than the 58% as initially presented. Moreover, comparing the UK average per person to the

corresponding value suggested by the Swedish national average from the waste composition analysis, the result would turn from the UK study presenting a higher value to the opposite where the average waste per person per week suggested by the Swedish national average is 0.89 kg. Additionally, one other aspect to consider it that both the UK study and the results from the present study are based on waste deriving from similar waste fractions which makes them possible to compare against each other. However, when wanting to compare the results from the present study against the official Swedish statistics that are reported on a national level by SEPA to the European Commission, there are more aspects to consider than average household size.

The food waste amounts that are reported as the official Swedish national figures are based on other waste streams than just the organic waste fraction as for the smart bins, questionnare and waste composition data used in the present study. The food waste reported by SEPA is primarily based on data from Waste Sweden. However, as opposed to the present study, all organic waste from all waste streams is included in the calculations, which means that e.g. food waste deriving from the residual waste fraction is also accounted for. Additionally, the weight of flowers, paper garbage bags and missorted items, which is estimated to constitute 20% of the weight, is subtracted from the total waste (Hultén et al. 2022). Based on the different ways of accounting for collected food waste, it becomes noticeable that factors that consider these differences need to be accounted for in order to make quantities comparable. In this regard, based on the results of the present study, if wanting to compare quantities obtained from smart bins, questionnaire and only the organic fraction from waste composition analysis to the figures presented by SEPA, the food waste from each method needs to be multiplied by approxemately 3, 5 and 1.3 respectively, in order to compensate for differences in accounting methods. However, as the quantaties from the smart bins and the questionnaire in the present study are based on food waste from four households, a more extensive study that includes more households would be required for determining more certain factors.

5.2 Questionnaire uncertainties

To meet the aim of the study and to fit into the applied definitions, the questionnaire presented by van Herpen et al. (2019a) was modified where some categories were removed and some new ones were added. A further option when categorising the state of the food thrown away was also added, namly *inedible parts*. Despite the attempt to make the questionnaire more coherent with the waste registered by the smart bins (which include all food and parts of food as well as other possible items thrown in the bins), the results from the questionnaire reported a significantley lower amount (57%) of waste than what was registered by the smart $bins_Q$. There

are, as previously discussed, several possible explainations with regards to human error to why the questionnaire was underreporting to the extent it did, but other possible explainations could also lie in the questionnaire itself. The estimations made by the participants on how much food was wasted in the relative amounts provided in the questionnaire were translated into actual weight by using average figures as suggested in the original questionnaire method. Since each answer option has a range in which the reported waste could be found, a sensitivity analysis was performed to see how assuming lower and higher values of weight corresponding to each answer option would influence the results. The sensitivity analysis showed that, despite using the corresponding maximum value for all selected answers, the waste reported through the questionnaire was lower than the waste registered by the smart $bins_Q$ in eight out of the total twelve weeks where food waste was recorded by these methods. Based on this finding, making adjustments to the assumed weight per unit applied when converting the relative measurements to absolute ones in the Household Food Waste Questionnaire could be a way to achieve more realistical results. An alternative approach would be to apply a factor to the calculated average quantities obtained from the questionnaire. The findings of the present study suggests that a factor of 2.3 could be appropriate, but further observations are necessary to increase confidence in this estimate. Also, an approach like that should be taken with care since it is not certain that a suggested factor would stay true to all studies and also since it could change over time, for instance if the generation of household food waste manages to decrease (Quested et al. 2020).

Besides the possibility to make adjustments to the weight estimations, there is also room for improvement on the answer options regarding quantities of wasted food when including inedible parts as done in the present study. In the original Household Food Waste Questionnaire, wasting more than the highest optional unit in some of the categories is less likely to happen when not including inedible parts. However, when including inedible parts into the questionnaire, wasting more than the maximum unit becomes more plausible for categories such as eggs and fresh fruits. Therefore, if adjusting the questionnaire to include inedible parts of food as done in the present study, the maximum option of amount wasted to select for certain categories should be contemplated. Additionally, the possible consequences of having a too low maiximum value is that it becomes difficult to calcuate/estimate the total weight of the waste. In this study, if “more than X unit” was selected, it was assumed that it ment plus one unit. However, in theory it could potentially have been plus ten units that were wasted. This could be another explanation for the underreporting found in the questionnaire, where in some cases the option “more than X units” were selected.

5.3 Limitations and future research

Since the aim of this study was to compare possible discrepancies in data when using different quantification methods, the criteria to what food waste should be included were limited to the waste thrown in the households' organic waste bin. This means a risk that the obtained figures do not correspond to the actual amount of total wasted food in the households since e.g. food or drinks poured down the drain, thrown into any other bin or given to the dog was not included. However, since all presented data was obtained from the same waste fraction (i.e. from the waste separately collected from the organic waste bin), the results from the methods can still be considered comparable. Moreover, for future studies that do not want to compare methods like in the purpose of this study, but instead evaluate the accuracy of what e.g. the smart bin can capture in terms of share of total food waste, a suggestion could be to have households both quantifying their food waste as in this study while also keeping a diary or another direct measurement that is more precise than the survey applied in the present study where all food not registered by the smart bin is accounted for in a more thorough manner. This would allow for even better understanding of household food waste quantities in its total. Another possibility for future research is to further investigate change of behaviour in food waste generation. This could be done by applying smart bins and a questionnaire over a more extended period of time where a greater number of households are studied so that seasonal fluctuations can be captured when also reaching a broader sample of the population.

Furthermore, this study investigated generated food waste quantities in four households using smart bins and a questionnaire. The average quantity of food waste registered by the smart bins during the questionnaire period (smart $bins_Q$) showed a lower precision than the average waste registered by the smart bins during the course of one year (which is to be expected as the longer period provided more data points). This gives an indication to that more data is required to obtain results that are more generalisable. More data could be obtained by e.g. including more households or using the smart bins for a longer period of time. Naturally, the most preferably option would be a combination of the two, however this is associated with higher costs and therefore not always realistic to achieve. Including more households but for a shorter period would on the one hand allow for a wider demographical spread while it on the other hand could risk behavioural changes influencing the outcomes or missing out on seasonal fluctuations. The corresponding counterpart would apply to using fewer households but for a longer period of time. Fewer households but for a longer period as in this study allow to provide data with higher accuracy. However, if assuming that the national statistics show at least semi-accurate figures, using fewer households infers a risk that they cannot be seen as representative to the larger scale due to, for instance, lack of

demographical spread or sample bias. Additionally, households participating in food waste quantification studies, regardless of applied method, do usually constitute a sample with a bias towards the subject since any participation is voluntarily and cannot be enforced, which is yet another factor to consider before making any general statements (Sharp et al. 2010; Graham-Rowe et al. 2015).

If studying the difference between the four participating households in this study, it becomes evident that there can be large differences in food waste quantities between households which advocates for the importance to include a sufficient sample size before drawing any conclusions on generated food waste amounts in more general terms. However, even within a small sample, studies investigating changes within the sample could provide an additional angle to the information provided through recordings of quantities. Since one of the main purposes of quantifying food waste is to be able to evaluate the efficacy of different actions and interventions targeting food waste reduction, having a direct measurement tool like the smart bins, which minimizes the possible impacts of human error as seen being a prominent matter for quantification methods like questionnaires, should therefore reasonably be used for this purpose. Therefore, future studies could use the benefits of the smart bins, which includes being more accurate than, e.g., questionnaires, being less time consuming than diaries and being able to provide results quicker and easier than waste composition analysis, to test the efficacy of different food waste reduction measures. When applying smart bins for evaluating the efficacy of interventions targeting food waste reduction, the reliability in data is not as dependent on the sample size as when using smart bins for general quantifications. This also speaks for minimizing the main downside of using smart bins with the purpose of quantifying food waste in general, namely the cost of having to implement a sufficient amount of them.

6. Conclusion

This study aimed to investigate differences in household food waste quantities obtained using smart bins, a questionnaire and existing national and local household food waste statistics. The result demonstrates differences in the quantities of household food waste depending on the method used. On average, the questionnaire underreported by 57% compared to the waste recorded by the smart $bins_Q$. In turn, the smart bins, underreported by on average 43% compared to the national statistics. Possible factors that can have influenced the difference in registered food waste quantities can be the influence of human subjectiveness, lack of demographical spread, a low highest optional unit in the questionnaire, and administrative factors. Due to differences in variables such as inclusion criteria, average household sizes and sizes of data sets, the comparison between the four households and the national and local statistics should be interpreted with care.

In order to achieve the goal of halving food waste at the consumer level by 2030 and contribute to a more sustainable food system with less food waste, it is necessary to implement waste-reducing actions that specifically target households. To assess the effectiveness of such actions, a reliable quantification scheme must be established, which requires further research on a valid method for quantifying household food waste. Although it may not be possible to generalize on a larger scale using the same variables and sample size, the difference in results between the smart $bins_Q$ and the questionnaire provides a valuable insight into the uncertainty associated with the questionnaire method for quantifying household food waste. Therefore, future research should focus on collecting more data from smart bins and including a sample with a wider demographic spread to improve the reliability of quantification methods.

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Popular science summary

Food waste is a problem that needs to be conquered to secure future generations' access to safe and nutritious food as wasting food infers constrains on both the environment, food security and economy. An important step towards reaching a sustainable future with less food waste is to develop and implement adequate methods for monitoring food waste amounts. This study aimed to compare three different methods used for quantifying household food waste, which all have their advantages and disadvantages. The compared methods were smart bin (where the organic waste bin is placed on a scale that records the waste as it occurs), questionnaire and waste composition analysis (where municipalities collect, sort and weigh the organic waste from the municipality).

The result showed that, using the questionnaire, the average reported food waste was 57% lower than the average food waste recorded by the smart bins. Possible reasons behind the difference between the smart bins and the questionnaire include possible biases, e.g. the participants intentionally underreporting, the participants not remembering what they had thrown away or weaknesses in the questionnaire design. When comparing the smart bins and the waste composition analysis method, the smart bins, on average, reported 43% less food waste than the waste composition analysis. Possible factors attributed to the difference could be lack of demographical spread for household participants using smart bins, differences in what type of waste that is included in the quantification, and other factors such as average household size. According to the result, the questionnaire method should not be considered a reliable method if the aim is to quantify household food waste. Further research must continue in the subject of finding the ultimate method for quantifying household food waste where the disadvantages are minimised and the advantages maximised.

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Appendix 1

This is the adjusted version of the Household Food Waste Questionnaire, which was based on the original version conducted by van Herpen et al. (2019a), that was distributed to the households participating in the study.

1. General information

Last week you received an email to pay close attention to what your household has thrown away in the organic waste bin during the previous week. This questionnaire will be about those products. As a reminder:

This questionnaire will be about:

- All products your household has thrown away in the organic waste bin in your home.
- This includes food products that are edible and inedible as well as other non-food products.
- It does not matter if it is a member of your household or if it is someone else that have wasted the item(s), everything should be included.

It will not be about:

- Drinks, liquids or other food products thrown away in the sewer or any other bin than the organic waste bin.

- Food products that are thrown away outside of the home (e.g. food thrown away in a restaurant or canteen).

2. What has your household disposed of in the past week?

Please tick the boxes of the products that are disposed of in your household in the past week. In case of complete meals, please report the main ingredients separately.

- Fresh vegetables and salads
- Non-fresh vegetables (jar / canned / frozen)
- Fresh fruit
- Non-fresh fruit (jar / canned / dried / frozen)
- Potatoes
- Potato products (fries, chips, baby or precooked potatoes, et cetera)

- Pasta
- Rice and remaining grains (including wraps, couscous, et cetera) Beans, lentils, chickpeas, et cetera.
- Meat (please report cold meat slices at “bread toppings”)
- Meat substitute
- Fish
- Bread toppings (cold meats slices, cheese slices, sweet topping, et cetera)
- Bread
- Cereals (muesli, granola, oat, brinta, et cetera)
- Cheese (cheese cubes, French cheese, sprinkle cheese. Excluded: cheese as bread topping)
- Eggs
- Soups / curry
- Candy / cookies / granola bars / chocolate bars
- Crisps / nuts
- Coffee grounds & tea leaves/bags
- Non food products (paper towel, flowers or flower/plant leaves)
- Other (non-listed foods, edible or inedible parts or any other products thrown in the organic waste bin)
- I have not thrown away any food or other products in the organic waste bin

3. Introduction to the next part of the questionnaire

Food waste states

We split food waste into several categories, which are explained below. Please read this carefully as these categories will be used in the next questions.

- Completely unused foods: food that is disposed of which has not been used at all. For instance, unopened packages, including unopened parts of multipacks, mouldy apples, dried leek, complete bread.
- Partly used foods: food that is disposed of after it has been partly used. For instance, a few bread slices, half a package of meat cuts, half an onion or half a package.
- Meal leftovers: leftovers that are disposed of after these were left on the plate, pots or pans. For instance, potato mash or rice that is left on the plate or in the pan, sandwiches that were not eaten during lunch.
- Leftovers after storing: meal leftovers that are disposed of after these were stored in the fridge or freezer to be eaten at a later moment. For instance, a frozen pasta portion.
- Inedible parts (e.g. shells, peels, bones, stones)

You will receive several questions about different type of food and possible other products your household has disposed in your organic waste bin of in the past week.

First, we ask how much of a certain product your household disposed of in the past week. Next, we ask to which category (unused, partly used, meal leftovers, leftover after it was stored) the majority of the disposed of food product belonged when it was disposed of. Please pay attention to which food product it refers!

4. Fresh vegetables and salads

In your household, how much fresh vegetables and salads were disposed of in the past week? One serving spoon equals 50 grams. As a reference: this equals half a leek, four mushrooms or the peel of 5 medium sized carrots.

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority) of the disposed of fresh vegetables and salads belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., a leek)
- Partly used foods: food that is disposed of after it is party used (e.g., half an union)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: Meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. peels or stones)

5. Non-fresh vegetables (jar / canned / frozen)

In your household, how many non-fresh vegetables (jar / canned / frozen) were disposed of in the past week? One serving spoon equals 50 grams. As a reference: this equals half a leak or four mushrooms.

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority of) disposed of non-fresh vegetables belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., unopened frozen / canned spinach package)
- Partly used foods: food that is disposed of after it is party used (e.g., half used frozen / canned spinach package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: Meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. peels or stones)

6. Fresh fruit

In your household, how many fresh fruits were disposed of in the past week? One apple or banana is one piece of fruit, regardless if it is the whole fruit or if it is only inedible parts (e.g. the peel). In case of small fruits, such as strawberries or grapes, one small bowl is considered 'one piece'.

- Approximately one fourth of a piece of fruit or less
- Approximately half a piece of fruit
- Approximately 1 piece of fruit
- 2 to 4 pieces of fruit
- More than 4 pieces of fruit

To which category did the (majority of) disposed of fresh fruit belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., an apple)
- Partly used foods: food that is disposed of after it is party used (e.g., half an apple that is not used in a dish)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans (e.g., half eaten apple or a fruit salad)
- Leftovers after storing: Meal leftovers that are disposed of after these were stored (e.g. fruit salad after it was stored)
- Inedible parts (e.g. peels or stones)

7. Non-fresh fruit (jar / canned / dried / frozen)

In your household, how many non-fresh fruits (jar / canned / dried / frozen) were disposed of in the past week?

One pear or peach from a can is one piece of fruit. In case of small fruits, as blueberries or tangerine wedges, one small bowl is considered 'one piece'.

- Approximately one fourth of a piece of fruit or less
- Approximately half a piece of fruit
- Approximately 1 piece of fruit

- 2 to 4 pieces of fruit
- More than 4 pieces of fruit

To which category did the (majority of) disposed of non-fresh fruit belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., unopened fruit can)
- Partly used foods: food that is disposed of after it is party used (e.g., half full fruit can)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans (e.g. bowl with fruit)
- Leftovers after storing: Meal leftovers that are disposed of after these were stored (e.g. fruit salad after it was stored)
- Inedible parts (e.g. peels or stones)

8. Potatoes

In your household, how many potatoes were disposed of in the past week?
One serving spoon equals 50 grams. As a reference: this equals half a midsize potato or the peel of 5 midsize potatoes.

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority of) disposed of potatoes belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete potato package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a potato package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans (e.g. smashed potato)
- Leftovers after storing: meal leftovers that are disposed of after these were stored (e.g. smashed potato after it was stored)
- Inedible parts (e.g. peels)

9. Potato products (fries, baby potatoes, precooked potatoes, et cetera).

In your household, how many potato products (fries, precooked potatoes, et cetera) were disposed of in the past week?

- Less than 10 fries / baby potatoes / pieces
- 10 to 25 fries / baby potatoes / pieces
- More than 25 fries / baby potatoes / pieces (approximately half a package of 500 gram)
- Full package (750 gram) fries / baby potatoes / pieces
- More than a package (750 gram) fries / baby potatoes / pieces

To which category did the (majority of) disposed of potato products belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete potato fries package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a potato fries package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. peels)

10. Pasta

In your household, how much pasta was disposed of in the past week? One serving spoon equals 50 grams.

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority of) disposed of pasta belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete pasta package)
- Partly used foods: food that is disposed of after it is party used (e.g., half pasta package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

11. Rice and remaining grains (including wraps, couscous, et cetera)

In your household, how much rice and remaining grains (including wraps, couscous, et cetera) was disposed of in the past week? One serving spoon equals 50 grams.

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority of) disposed of rice belong?

Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete rice package)
- Partly used foods: food that is disposed of after it is party used (e.g., half rice package)
- Meal leftovers: meal leftovers that are disposed of after it was left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after it was stored
- Inedible parts

12. Beans, lentils, chickpeas, et cetera

In your household, how much beans, lentils, chickpeas, et cetera were disposed of in the past week?

- Less than one serving spoon
- 1 to 2 serving spoons
- 3 to 4 serving spoons
- 5 to 6 serving spoons
- More than 6 serving spoons

To which category did the (majority of) disposed of beans, lentils, chickpeas, et cetera belong?

Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., unopened bean jar)
- Partly used foods: food that is disposed of after it is party used (e.g., half full bean jar)
- Meal leftovers: meal leftovers that are disposed of after it was left on the plate, pots or pans

- Leftovers after storing: meal leftovers that are disposed of after it was stored
- Inedible parts

13. Meat

In your household, how much meat was disposed of in the past week? A portion refers to one chicken breast, one steak, et cetera. In case of smaller pieces, as minced meat, try to estimate it in whole pieces of meat (e.g., one package of minced meat equals two portions).

- Approximately half a portion or less
- Approximately one portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of meat belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., sausage package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a sausage package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. bones)

14. Meat substitutes

In your household, how much meat substitutes were disposed of in the past week? A portion refers to a vegetarian burger, et cetera. In case of smaller pieces, as minced meat, try to estimate it in whole pieces of meat (e.g., one package of minced vegetarian meat equals two portions).

- Approximately half a portion or less
- Approximately one portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of meat substitutes belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., vegetarian burger package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a vegetarian burger package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

15. Fish

In your household, how much fish was disposed of in the past week? A portion refers to one fish fillet, one piece of salmon, the skin and bones of one fish fillet et cetera.

- Approximately half a portion or less
- Approximately a complete portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of fish belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete fish package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a fish package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a fish package)
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. bones and skin)

16. Bread toppings (cold meats slices, cheese slices, sweet topping, et cetera)

In your household, how much bread toppings (cold meats slices, cheese slices, sweet topping, et cetera) were disposed of in the past week? One portion is what is used on one slice of bread / sandwich / portion of baguette.

- Approximately half a portion or less
- Approximately a complete portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of bread toppings belong? Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete package with meat slices)
- Partly used foods: food that is disposed of after it is party used (e.g., half a package with meat slices)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. cheese rind)

17. Bread

In your household, how much bread was disposed of in the past week? A bun, portion of baguette or sandwich is similar to one slice of bread.

- Less than one slice of bread
- One or a few slices of bread
- Approximately half a loaf
- Approximately one loaf
- More than one loaf

To which category did the (majority of) disposed of bread belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., whole loaf)
- Partly used foods: food that is disposed of after it is party used (e.g., slices of bread)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans (e.g., bread crusts)
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

18. Cereal (muesli, granola, oat, porridge, et cetera)

In your household, how much cereal (muesli, granola, oat, porridge, et cetera) was disposed of in the past week? A portion is the amount of cereals used for one bowl of breakfast.

- Less than half a portion
- A half to one and a half portion
- Multiple portions (approximately half a package)

- Approximately a complete package
- Multiple packages

To which category did the (majority of) disposed of cereals belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete cereal package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a cereal package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

19. Cheese (cheese dices, French cheese, sprinkle cheese; excluded: cheese as bread topping)

In your household, how much cheese (cheese dices, French cheese, sprinkle cheese; excluded: cheese as bread topping) was disposed of in the past week? A handful of cheese can be seen as a dice of cheese.

- Less than one dice of cheese
- Approximately one dice of cheese
- 1 to 3 cheese dices
- 4 to 5 cheese dices
- More than 5 cheese dices

To which category did the (majority of) disposed of cheese belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete French cheese)
- Partly used foods: food that is disposed of after it is party used (e.g., partly used French cheese)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. cheese rind)

20. Eggs

In your household, how many eggs were disposed of in the past week? In case of inedible parts (shells), please select the corresponding number of whole eggs.

- Less than 1 egg
- 1 egg
- 2 to 3 eggs
- 4 to 5 eggs
- More than 5 eggs

To which category did the (majority of) disposed of eggs belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete eggs)
- Partly used foods: food that is disposed of after it is party used (e.g., egg white)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. egg shell)

21. Soups / curry

In the household, how much soup / curry was disposed of in the past week?

- Less than half a ladle
- Half to one and a half ladle
- Multiple ladles (approximately half a litre)
- Approximately 1 litre
- More than 1 litre

To which category did the (majority of) disposed of soup belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., complete soup package). Not applicable in case of home-made soup
- Partly used foods: food that is disposed of after it is party used (e.g., half a soup package). Not applicable in case of home-made soup
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans (warmed
- package of soup or home-made soup)
- Leftovers after storing: meal leftovers that are disposed of after these were stored

- Inedible parts

22. Candy / cookies / granola bars / chocolate bars

In your household, how much candy / cookies / granola bars / chocolate bars were disposed of in the past week? A portion is a handful of sweets, small chocolate bar, a cookie, et cetera.

- Approximately half a portion or less
- Approximately one portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of candy belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., one cookie package)
- Partly used foods: food that is disposed of after it is party used (e.g., half a cookie package)
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

23. Crisps / nuts

In your household, how much crisps / nuts were disposed of in the past week? A portion is a handful of crisps or nuts.

- Approximately half a portion or less
- Approximately one portion
- 2 to 3 portions
- 4 to 5 portions
- More than 5 portions

To which category did the (majority of) disposed of crisps / nuts belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all (e.g., bag of crisps)
- Partly used foods: food that is disposed of after it is party used (e.g., half a bag of crisps)

- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts (e.g. shell)

24. Coffee grounds & tea leaves/bags

In your household, how much coffee grounds/tea leaves/bags were disposed of in the past week? One cup of coffee corresponds to approximately 20g coffee grounds (wet weight). One used tea bag is approximately 10g.

- Less than 50 g
- 50 – 150 g
- 150 – 250 g
- 250 - 350 g
- More than 350 g

To which category did the (majority of) disposed of Coffee grounds and Tea leaves/bags belong?

Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: coffee or tea leaves/bags that are disposed of which are not used at all
- Leftovers after storing: coffee or tea leaves/bags that are disposed of after these were stored
- Inedible parts

25. Non food products (paper towel, flowers or flower/plant leaves)

In your household, how much non-food products were disposed in the past week?

- Less than 50 g
- 50 – 150 g
- 150 – 250 g
- 250 – 350 g
- More than 350 g

26. Other (non-listed foods, edible or inedible parts or any other products thrown in the organic waste bin)

In your household, how much other products have been thrown away in the organic waste bin in the previous week?

- Less than 50 g
- 50 – 150 g
- 150 – 250 g
- 250 – 350 g

- More than 350 g

To which category did the (majority of) disposed of Other belong?
Please tick the category that occurred the most. You can tick more than one box if multiple categories occurred in the same amount.

- Completely unused foods: food that is disposed of which is not used at all
- Partly used foods: food that is disposed of after it is party used
- Meal leftovers: meal leftovers that are disposed of after these were left on the plate, pots or pans
- Leftovers after storing: meal leftovers that are disposed of after these were stored
- Inedible parts

Thank you for your participation. See you again next week.

Appendix 2

Assumed values for calculating food waste quantities based on reporting from the questionnaire. The range for each answer option is indicated by minimum and maximum values in parenthesis.

	Answer option 1	**Answer option 2**	**Answer option 3**	**Answer option 4**	**Answer option 5**
Product category	**Average (min; max)**	**Average (min; max)**	**Average (min; max)**	**Average (min; max)**	**Average (min; max*)**
Fresh vegetables and salads	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Non-fresh vegetables	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Fresh fruit	25 (1 ; 38)	50 (39 ; 75)	100 (76 ; 200)	300 (201 ; 400)	500 (401 ; 600)
Non-fresh fruit	20 (1 ; 30)	40 (31 ; 60)	80 (61 ; 160)	240 (161 ; 320)	400 (321 ; 480)
Potatoes	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Potato products	25 (1 ; 57)	88 (58 ; 232)	375 (233 ; 563)	750 (564 ; 938)	1125 (939 ; 1312)
Pasta	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Rice and remaining grains	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Legumes	25 (1 ; 50)	75 (51 ; 113)	150 (114 ; 200)	250 (201 ; 300)	350 (301 ; 400)
Meat	75 (1 ; 113)	150 (114 ; 263)	375 (264 ; 525)	675 (526 ; 788)	900 (789 ; 1050)
Meat substitute	45 (1 ; 68)	90 (69 ; 158)	225 (159 ; 315)	405 (316 ; 473)	540 (474 ; 630)
Fish	75 (1 ; 113)	150 (114 ; 263)	375 (264 ; 525)	675 (526 ; 788)	900 (789 ; 1050)
Bread toppings	10 (1 ; 15)	20 (16 ; 35)	50 (36 ; 70)	90 (71 ; 105)	120 (106 ; 140)
Bread	18 (1 ; 27)	35 (28 ; 218)	400 (219 ; 600)	800 (601 ; 1000)	1200 (1001 ; 1400)
Cereals	10 (1 ; 25)	40 (26 ; 145)	250 (146 ; 375)	500 (376 ; 750)	1000 (751 ; 1250)
Cheese	5 (1 ; 8)	10 (9 ; 15)	20 (16 ; 33)	45 (34 ; 53)	60 (54 ; 70)
Eggs	30 (1 ; 45)	60 (46 ; 105)	150 (106 ; 210)	270 (211 ; 315)	360 (316 ; 420)

Soups / curry	38 (1 ; 94)	150 (95 ; 325)	500 (326 ; 750)	1000 (751 ; 1250)	1500 (1251 ; 1750)
Candy / cookies / bars	10 (1 ; 15)	20 (16 ; 35)	50 (36 ; 70)	90 (71 ; 105)	120 (106 ; 140)
Crisps / nuts	10 (1 ; 15)	20 (16 ; 35)	50 (36 ; 70)	90 (71 ; 105)	120 (106 ; 140)
Coffee grounds / tea leaves	25 (1 ; 63)	100 (64 ; 150)	200 (151 ; 250)	300 (251 ; 350)	400 (351 ; 450)
Non food products	25 (1 ; 63)	100 (64 ; 150)	200 (151 ; 250)	300 (251 ; 350)	400 (351 ; 450)
Other	25 (1 ; 63)	100 (64 ; 150)	200 (151 ; 250)	300 (251 ; 350)	400 (351 ; 450)

* Maximum value assumed to be plus one unit.

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