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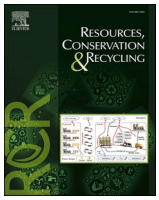

Full length article

The Swedish *fika* down the drain

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ABSTRACT

Considering coffee's significant social role, reducing coffee waste is pivotal. We quantified liquid coffee waste generated in the Swedish food service sector and explored causes and potential mitigation measures. We combined quantitative data from 76 days across six restaurants with qualitative insights. The results showed that 10% of brewed coffee is wasted daily, corresponding to 3.3 kg restaurant/day, 13 g customer/day and 739 g employee/day. When extrapolated to national scale, these findings suggest that Swedish restaurants generate approximately 17,800 tonnes of coffee waste annually. Thus liquid coffee waste represents a previously unaccounted for 21% increase in food waste, not including waste left in consumers' cups. We identified cost savings as a motivator for waste reduction and time constraints as a significant barrier. These findings provide a more comprehensive understanding of food service waste, while also highlighting the need for inclusion of liquid waste in national statistics and for policy intervention.

1. Introduction

With a growing global population, consumption of coffee is increasing (Quadra et al., 2020). The estimated global trade value of the coffee industry is USD 38 billion, or 2.5% of the total trade value in agricultural commodities (International Trade Centre, 2021). In 2020, worldwide production of green coffee beans was approximately 11 million tons (FAOSTAT, 2023), supplying a diverse range of coffee beverages for consumers worldwide. However, coffee production has environmental costs, e.g. 1 kg of ground coffee powder generates an estimated 4.0 kg CO_2e, contributing to climate change (Eneroth et al., 2022), with the majority of this impact originating from the production phase. The industry also has significant effects on biodiversity, primarily due to deforestation to expand cultivation areas (Ahlgren et al., 2022). Moreover, fertiliser and pesticide use in coffee cultivation is comparatively high, leading to greenhouse gas emissions, climate change and eutrophication as associated environmental concerns (Ahlgren et al., 2022; Cederberg et al., 2019; Ho et al., 2022; Moberg et al., 2020).

Coffee consumption plays an important role in social life worldwide, and especially in Scandinavia (Kjeldgaard and Ostberg, 2007). From a global perspective, Sweden has the third highest per capita coffee consumption (International Trade Centre, 2021). Between 2010 and 2020, yearly per capita consumption of roasted coffee in Sweden increased from 7.5 to 8.8 kg (Swedish Board of Agriculture, 2023). Translated into amount of coffee consumed by Swedish adults, this corresponds to on average 280 mL of brewed coffee per day (Lundberg-Hallén and Öhrvik, 2015).

Given the significant environmental impact of high coffee consumption, the World WildLife Fund (WWF) included hot beverages in its 2022 consumer guide, which encourages use of organically certified coffee and stresses the importance of minimising waste (WWF, 2022). Wasting food means that the resources required to produce and deliver the final product were used in vain (Johnson, 2020). This applies also for liquids such as coffee, as such products are considered food (European Commission, 2002). Preventing waste of coffee beverages therefore not only avoids waste of resources, but also avoids the environmental impact linked to utilisation of those resources (Büsser et al., 2008).

To minimise the negative effects caused by food waste generation, several institutions have included this aspect in their goals. In 2015, the United Nations (UN) set the target of halving per capita global consumer food waste by the year 2030 (United Nations, 2015). The same target is included in the Farm to Fork Strategy introduced by the European Union (EU) (European Union, 2020). Additionally, one of the milestone targets in the Swedish environmental objectives system is to reduce the total mass of food waste by 20% between 2020 and 2025 (Swedish Environmental Protection Agency, 2023).

An essential step in achieving the goal of reduced food waste is quantification, in order to obtain clear data on food waste levels and

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compare these with set reduction targets (Geislar, 2020; Xue et al., 2017). Several standards have been developed to improve methodological practices in food waste quantification, but the definitions and scope of each standard vary and liquid waste is excluded frequently (European Commission, 2022; International Food Waste Coalition, 2022; Swedish National Food Agency, 2023; Tostivint et al., 2016; UNEP, 2021; World Resources Institute, 2016). Excluding specific food categories or waste streams may overlook places where significant food waste occurs and where preventive measures are necessary to reduce waste and meet reduction targets.

Food waste is generated at all stages of the supply chain to different extents and by different causes (Parfitt et al., 2010). United Nations Environment Programme (UNEP) estimates of food waste levels at the consumption stages of the supply chain indicate that households are responsible for the greatest share of global food waste (61%), while the food service sector accounts for the second greatest share (26%) (UNEP, 2021). However, these estimates are based on solid food waste, while information on liquid food waste generation is limited. Estimates gained through surveys by the Swedish Environmental Protection Agency (2021) showed that 190,000 tons of food and beverages were wasted via Swedish household drains in 2020 and that almost 45% of this waste was tea or coffee. These 190,000 tons represent 23% of total household food waste in Sweden (Swedish Environmental Protection Agency, 2022). However, estimates of liquid food waste in other parts of the Swedish food supply chain are lacking.

Few previous studies on the food service sector have included liquid food waste, and the methods used and the results obtained have varied. A study by Ahmed et al. (2018) quantified food waste, including liquids, in a university dining hall in the United States and found that around 19% of total waste consisted of post-consumer liquid waste (beverages and soups). A study by Sehnem et al. (2022) on the Brazilian food service sector, using survey methodology, showed that 4% of total waste came from drinks or desserts. Differences in scope in previous studies and limited definitions of the food categories and waste streams included make it difficult to compare results. Overall, however, the results indicate that liquid food waste occurs and that more research is needed to quantify this waste. As mentioned, the food service sector is a large contributor to food waste. It also has many entities, visitors and high levels of production, so a decrease in food waste generation could help reduce the negative impacts of this sector (Heikkilä et al., 2016). Coffee is offered in most food service establishments, making it a relevant food category to focus on when exploring levels of liquid food waste in the sector.

Identifying sources of food waste is an essential initial step in prevention, as it provides an indication of where efforts should be targeted. Moreover, when developing interventions for effectively reducing food waste, an understanding of the underlying causes of waste generation is needed. The extent to which coffee beverages are wasted in the food service sector is currently unknown, as are the types of waste prevention measures needed to reduce coffee waste and minimise its negative effects. The research questions for this study therefore are:

1. How much coffee waste is generated in the Swedish food service sector
2. What are the primary causes of coffee waste in the Swedish food service sector
3. Why is coffee waste often neglected in waste quantification studies

2. Material and methods

This research took the form of a mixed methods case study, where both quantitative and qualitative methods were applied. The quantitative part of the study involved quantifying actual levels of coffee waste in restaurants. The qualitative part comprised semi-structured interviews with the restaurants taking part in quantifications and an online survey of non-participating food service establishments.

In addition to quantifying coffee waste generated in the Swedish food service sector and identifying the underlying causes, perceived barriers to quantification of coffee waste were examined. In Swedish restaurants, coffee is commonly brewed using drip filter coffee machines and is sold as individual cups or as part of a meal, e.g. lunch. In this study, coffee waste was defined as the liquid part of filter coffee i.e. drinkable coffee. This only refers to the volume prepared but not served and eventually becoming waste from the coffe machines or containers. This does not include the solid part, i.e. coffee grounds, that is normally not consumed. This study also did not include post-consumer waste i.e. consumer leftovers in cups that was eventually wasted. The food service sector was defined as *"establishments or actors providing complete meals or drinks fit for immediate consumption, whether in traditional restaurants, self-service or take-away restaurants, whether as permanent or temporary stands with or without seating. Decisive is the fact that meals fit for immediate consumption are offered, not the kind of facility providing them"* (EUROSTAT, 2008).

2.1. Quantification and analysis of coffee waste

Recruitment for the study targeted food service establishments offering filter coffee to consumers, specifically including cafés, restaurants, conference centres and hotels in Sweden. Selection was random, but geographically convenient. Initial contact with potential participants was made through email, providing study details and inquiring about their interest in participation. Non-respondents received a follow-up reminder. Of 201 establishments contacted across five Swedish cities, 56 declined and 139 did not reply. Ultimately, six restaurants engaged in the waste quantification process and four of these participated in subsequent interviews. Information about the restaurants participating in the study are summarised in Table 1.

Coffee waste was quantified in the six participating food service restaurants (A-F) for a total of 76 days between October and December 2023, with the duration of participation ranging from 5 to 22 days per restaurant (Table 1). The variation in quantification days was due to each restaurant's capacity and willingness to engage in the study. Staff members carried out daily quantifications, using the instructions and digital and printed sheets provided (Table S1 in Supplementary Information (SI)), and a weighing scale was supplied if lacking at the establishment. Coffee waste was collected and weighed on digital scales at restaurants A, C, D and E, while restaurant B measured it in litres. The collected data included the volume of coffee produced daily and the total guest count, recorded on the quantification sheets. At restaurant F, quantification was performed by one of the authors, to serve as validation.

Table 2.

Coffee waste was analysed using three different indicators (per guest, per employee and in relation to the total mass of coffee brewed) and presented as descriptive statistics. The total volume of coffee brewed was estimated using coffee machine indicators, rather than by weight. It was assumed that 1 kg of liquid coffee is equivalent to 1 L. For statistical validity, only days with complete data entries, including the amount of coffee produced, number of guests and quantity of waste, were considered in the analysis. This criterion led to the exclusion of data from one day at restaurant C (day 7).

2.2. Understanding waste causes and quantification motivators

To complement the quantitative data, semi-structured interviews were conducted with representatives from four of the six restaurants. The purpose of these interviews was to identify the reasons behind coffee waste and to explore the obstacles and incentives relating to its quantification. The interview format included 10 open-ended questions designed to elicit insights on the motivation of establishments for participating in the study, perceptions on coffee waste issues and reactions to the levels of waste identified at their establishment (Table S2

Table 1
Participating restaurants and their characteristics

Restaurant	Participated in interviews	Quantification days	Business type	Guests/day (average)	Employees (n)
A	Yes	22	Lunch restaurant and café in office building	63	2
B	Yes	10	Lunch restaurant for seniors	144	4
C	Yes	20	Campus lunch restaurant and café	192	5
D	Yes	10	Staff canteen and café	600	6
E		10	Campus café	622	3
F		5	Lunch restaurant and café in office building	548	7

Table 2
Parameters and distributions used in calculations and Monte Carlo simulations of Swedish coffee waste (in tonnes) per year

Parameter	Distribution	Description
Employees in Swedish restaurants Mode: 92 695±2.5%	Triangular	Based on statistics provided by Statistics Sweden and the SNI code 56100.
Number of days open per year Estimated based on assumptions.	Triangular	Min: 156, Mode: 260, Max: 365
Waste per employee (g)	Fitted	Fitted from collected data, zeroes removed but introduced as a fraction of their occurrence in the Monte Carlo simulations.

in SI). These interviews were carried out following the quantification phase.

In addition to the interviews, a confidential online survey was disseminated in October 2023 to the 195 restaurants that either did not respond or declined to participate in the waste quantification step. Two reminders were issued to increase response rates. The survey was accessible for 50 days on Netigate, a survey platform, and comprised both open-ended and multiple-choice questions (Table S3 in SI). These sought to understand the reasons for non-participation, incentives that might encourage waste quantification and perspectives on coffee waste causes within their own operations and more broadly. Respondents had the option to provide contact details for potential follow-up interviews. The survey garnered 18 complete responses, with no respondents opting to provide contact information. However, a single response could represent multiple restaurants, especially those under the same corporate management, implying a higher effective response rate in terms of the number of establishments represented.

Responses from the semi-structured interviews and the online survey were systematically analysed. They were initially sorted into categories related to the causes of liquid coffee waste, barriers to quantifying coffee waste, and drivers encouraging quantification. These preliminary groupings were further refined into themes (Braun and Clarke, 2006), based on common elements. The frequency of each response type was recorded and summarised. It is important to note that the data did not distinguish between waste generated during preparation, during serving or by consumers, but rather addressed coffee waste as a whole.

2.3. Extrapolating coffee waste to national level

To calculate and compare the amount of coffee waste (in tonnes) generated in the Swedish food service sector, *coffee waste per employee (g)* was multiplied by *number of employees in the sector* and *days open per year* (Equation 1). This procedure scaled the coffee waste per employee and yielded a value in tonnes per year, which is similar to how solid waste in the food service sector is scaled up to national level (Swedish Environmental Protection Agency, 2022).

Monte Carlo simulations were used to complement the calculated value and to estimate the uncertainty range in the final tonnes per year factor. The simulations were performed 10,000 times, with variability captured using different distributions. These distributions were assumed based on data collected, literature and our own assessment.

The parameter *waste per employee* was modelled using various statistical distributions (Table S4 in SI), with the three distributions demonstrating the lowest Akaike information criterion (AIC) values ((Gamma, Exponential, LogNormal)) selected for use in simulations (Burnham and Anderson, 2004).

The simulations provided a comparative analysis against the extrapolated coffee waste value, thereby testing the sensitivity of the model to variations in the underlying *waste per employee* parameter.

$$\textit{Coffee waste per year}\,(\textit{tonnes}) = \textit{Number of employees in Swedish restaurants} * \textit{Number of days open per year} * \textit{waste}\,(g)\,\textit{per employee} * 10^{-6} \quad (1)$$

Calculated deterministic coffee waste was also compared with the solid food waste generated within the Swedish restaurant sector. Coffee waste in tonnes was also expressed per capita, as an additional way to compare the results for different parts of the food supply chain.

3. Results

The 76 days of waste quantification across six restaurants in various locations in Sweden indicated that around 10% of all brewed coffee was discarded by these restaurants, not accounting for waste from customers. On average, coffee waste amounted to roughly 3.3 kg per restaurant per day, 13 g per customer per day and 739 g per employee per day. Table 3 shows descriptive statistics for these indicators.

There was great variation within the individual restaurants, where daily coffee waste ranged from 0 to 40% (Fig. 1). Restaurant F had the lowest median waste percentage (4%), but also recorded waste for the smallest number of days (5). Restaurant A had the highest median waste percentage (around 11%), recorded over 22 days. Most restaurants exhibited occasional spikes in waste, resulting in their waste distribution patterns having a skewed distribution.

Despite restaurant A recording the highest median percentage of coffee waste, it produced the lowest volume of coffee (Fig. 2). Its daily coffee production fluctuated between 2 and 130 kg, while its coffee waste varied from 0 to 13 kg. Restaurant D was the largest coffee producer, with daily quantities ranging from 110 to 130 kg, but its waste mass overlapped with that of restaurants E and C, which had brewing volumes of 27 kg to 65 kg, respectively (Fig. 2). Columnar patterns were observed for brewed coffee amount, indicated that coffee is produced in batches. Therefore a day's production is made up of a number of batches, rather than the exact number of cups needed to fulfil customer demand.

A noteworthy finding was that throughout the quantification period and across all restaurants, there was a complete absence of waste during the coffee preparation process.

Table 3
Summary of descriptive statistics on observed coffee waste indicators, compiled from daily data (n = 76) across all six Swedish restaurants participating in coffee waste quantification

Indicator/per day	Min	Q1	Median	Q3	Max	Mean	Std	Lower 95% CL mean	Upper 95% CL mean
Waste (g)	0	423	2150	5138	12500	3262	3241	2521	4003
Waste per guest (g)	0	5	9	15	83	13	16	10	17
Waste per employee (g)	0	200	520	1071	2633	739	684	583	895
Waste (%)	0	4.9	7.7	14.5	40.0	10.5	8.6	8.5	12.5

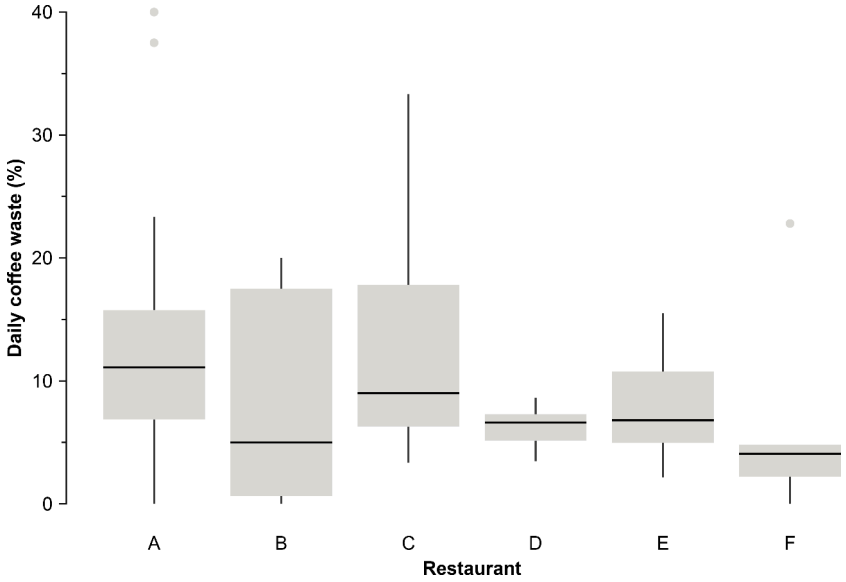

Fig. 1. Boxplot of coffee waste (%) in the six participating Swedish restaurants (A-F) based on daily quantification data (n = 22, 20, 19, 10, 10, 5). Centre lines show the median, box limits the 25th and 75th percentiles (determined by Julia software) and whiskers 1.5 times the interquartile range (25th to 75th percentile). Outliers are represented by dots.

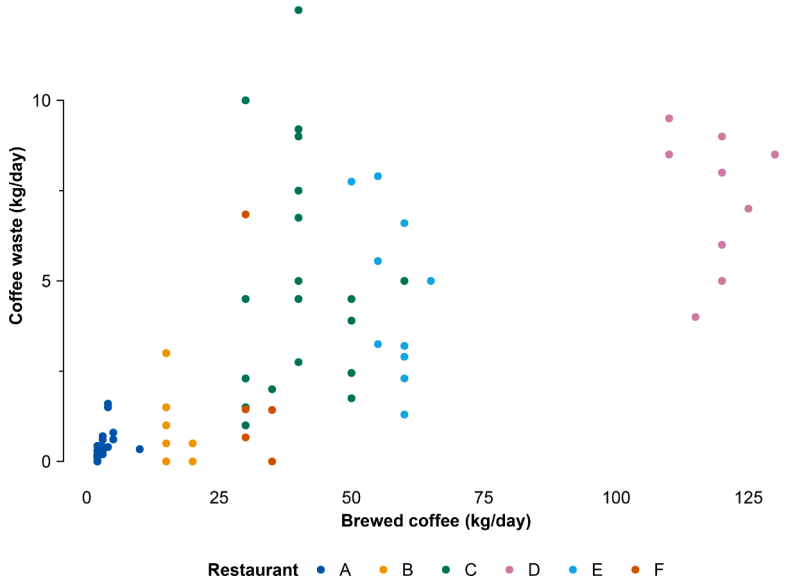

Fig. 2. Relationship between the amount of liquid coffee produced and daily coffee waste generation in the different restaurants (A-F).

3.1. Causes of coffee waste and drivers and barriers to quantification

There was a significant issue of coffee overproduction, which was a notable source of waste (Table 4). Analysis of the interview and survey data indicated that this tendency to overproduce stemmed from concerns about potential shortages of coffee before the end of the day, coupled with an inability to forecast daily consumption. Factors contributing to these problems included unpredictable number of guests and the resulting coffee demand, lack of time to analyse customer flow, and pressure that coffee must always be freshly available. The challenge of coffee overproduction was exaggerated in restaurants where coffee was included in the meal price or offered with free refills, as this

Table 4
Causes of coffee waste, barriers, and drivers for quantification according to the Swedish restaurants interviewed (n=4) and surveyed (n=18) in this study

Causes of coffee waste		
Theme	Response	Answers (n)
Production strategies	Concerns regarding coffee shortages, tendency to overproduce due to demand issues	15
	There must be coffee to offer	3
	Measuring out coffee grounds for half-sized brews is time-consuming	1
	Coffee tends to lose its flavour over time, necessitating a fresh brew	1
Lack of resources	Lack of attention to customer flow or time to analyse it, due to high workload	6
	Coffee machine does not allow brewing less than full batches	1
Business offer	Coffee is included in meal/uncharged, making customer demand difficult to understand	2
	Free refill of coffee is included in the price, making customer demand unpredictable	1
Drivers of quantification		
Theme	Response	Answers (n)
Awareness	Minimising waste leads to cost savings	10
	Environmental considerations, sustainability, and waste reduction	6
	Feels sad to waste food	2
	Able to leverage the outcomes of quantification efforts	1
Demand from outside	Demand from company or industry	3
	Demand from guests to prevent coffee waste	1
Resource efficiency	Reducing waste decreases the workload	2
	Conserving resources	1
Barriers to quantification		
Theme	Response	Answers (n)
Lack of resources	Don't have time to quantify coffee waste	19
	Cost of staff to perform quantification	1
	It is unreasonable and difficult to quantify waste	1
Low or non-existent waste	Already know how much is wasted	3
	Have low level of coffee waste and see no point in quantifying	2
	Operate a small-scale coffee production and consider quantification unnecessary	1
	Low waste due to serving waste being re-used	1
Scepticism about the issue	Difficult to do something about coffee waste	3
	Viewed as a minor and insignificant issue	3
	Coffee waste is unavoidable	1
Team structure	Staff variability complicates the quantification process	2
	Insufficient staffing to perform quantification	1

complicated consumption predictions. This problem was summarised thus in a comment by one interviewee: "We offer coffee with free refills, which makes it more difficult to predict. From ten sold coffees, consumption can double to twenty cups". The trend for overproduction was also influenced by the cultural perception of coffee as a readily available commodity, as reflected in this statement by another respondent: "There's a well-established expectation for unlimited coffee consumption. It's a balance between running out of coffee or having too much at the end of the day".

Another aspect related to infrastructure and time. One respondent identified a key infrastructure limitation contributing to coffee overproduction, namely that coffee machines are designed to brew only full batches. This design constraint compels production of excess coffee, as there is no option for smaller quantities. Other respondents echoed this sentiment and reported additional practical difficulties, such as the time-intensive process of precisely measuring coffee grounds for anything less than a full batch, which further exacerbates the waste issue.

Survey results showed that most entities (11 out of 18) actively measure solid food waste, aiming to reduce waste while monitoring costs and sales. This demonstrates a proactive approach towards waste management. Regular measurement of solid food waste was confirmed by two interviewees. While coffee waste quantification was deemed straightforward by all interviewees, with two managing it with minimal team assistance, there was variance in engagement levels due to perceived difficulties in team involvement. Those who did not engage in measuring coffee waste cited negligible amounts or did not view it as an issue.

Overall, there was good awareness of coffee waste among the respondents, with 19 recognising its significance (Table 4), motivated and driven by financial, environmental or emotional factors. In addition, there was an expressed external push from companies, the industry or customers towards addressing coffee waste and quantifying it. In addition to this, respondents mentioned environmental aspects and not wasting food as important and a way to save on resources, e.g. less waste results in less work to get rid of the waste. One restaurant recognised the intrinsic value of waste quantification data for organisational benefits, suggesting that such metrics can inform and improve operational efficiency. However, only one restaurant stated that it will continue with quantification of coffee waste.

Time constraints were a prominent barrier to quantifying coffee waste according to the restaurants. Respondents also cited organisational challenges, including the absence of structured teams able to integrate new tasks effectively. There was also the aspect of people not viewing the problem as large enough and feeling that change is difficult to achieve. Some entities do not measure waste, believing their levels are too low for quantification or because they feel sufficiently informed about their waste patterns. Notably, two survey responses indicated that the use of automatic coffee machines, which are believed to generate no waste, eliminates the need for waste tracking.

3.2. *Coffee waste extrapolated to national level*

When the collected data were extrapolated to national level, the results showed that around 17,800 tonnes of coffee waste are generated annually in Sweden. As shown in Table 5, this nationwide estimate was compared with values obtained in simulations. The mean figures derived from the Gamma and Exponential distribution were nearly equivalent to the extrapolated national figure. However, the median value from the LogNormal distribution simulations, based on identical parameters, was about 11.5% higher (+2,049 tonnes).

Table 5
Extrapolated coffee waste (tonnes per year, t/y) in Sweden compared against the outcomes from Monte Carlo simulations, performed 10,000 times, with variability captured using different distributions (Gamma, Exponential, LogNormal). The simulated values are mean ± two standard deviations for each distribution model. The figures are not rounded, but the number of significant digits does not indicate high precision.

Method	Coffee waste (t/y)
Extrapolated	17,812
Simulated	
Gamma	17,840±339
Exponential	17,836±383
LogNormal	19,861±597

The simulations using the Gamma and Exponential distributions suggested that the average amount of coffee waste produced annually by the Swedish food service sector is around 17,800 tonnes, with a margin of error of ~340-380 tonnes (accounting for two standard deviations). Compared with the solid food waste generated by the Swedish food service sector annually, which amounts to 65,000 tonnes, coffee waste represented about 21% of total food waste. Coffee waste per capita in Sweden based on these results was estimated to be 1.7 kg/capita/year.

4. Discussion

Understanding where food waste comes from is essential to prevent its generation. This study showed that 10% of coffee brewed in Swedish food service establishments is never served to customers and is left in the brewing machine to be discarded. When this figure is extrapolated to national level, it suggests that the Swedish restaurant sector generates roughly 17,800 tonnes (margin of error ± 380 tonnes) of liquid coffee waste every year. This is in addition to the 65,000 tonnes of solid food waste already identified in the Swedish restaurant sector. Thus coffee waste represents a previously unaccounted for 21% increase in waste, not including waste left in consumers' cups. This fraction of waste amounts to around 1.7 kg per person per year, which can be compared with 135 kg of overall food waste per person each year in the whole supply chain (Swedish Environmental Protection Agency, 2024) .

Considering UN Sustainable Development Goal 12.3, which aims to cut food waste in half by the year 2030, these results suggests that the target reduction for coffee waste should be around 5%, depending on the volume of coffee waste left in cups. However, achieving this reduction target for coffee waste may pose varying challenges for different restaurants that serve coffee, since not all restaurants share the same operational traits. For example, those establishments that brew the largest quantities of coffee daily do not necessarily generate the highest rates of waste in proportional terms. Prior research on solid food waste suggests that establishments generating the most waste (where previous interventions have not been made) have the greatest potential for reduction (Eriksson et al., 2019). Quantifying food waste in such establishments could be an effective first step in addressing the issue. By doing so, these establishments could probably achieve rapid initial reductions in waste (low-hanging fruit). This scenario is probably also applicable to liquid waste as a whole, and specifically to coffee waste.

A significant limitation of this study is that it was based on quantification data from only six restaurants, and thus the findings only provide an initial insight into liquid waste issues. Over 200 restaurants were invited to participate in this study, but only six agreed to do so. This likely resulted in a selection bias where only the most interested restaurants participated, potentially influencing the results (Canali et al., 2017; Silvennoinen et al., 2019). However, such selection bias is not unique to this study. The range of waste levels recorded was broadly consistent with the variation reported in other studies on solid waste, where the level ranged from 0% to 40% of the food served per meal (Eriksson et al., 2017; Malefors et al., 2022, 2019)This study showed that quantifying coffee waste in restaurants was a barrier for many of the staff (surveyed and interviewed), with most of the 19 respondents claiming that they did not have time to quantify the amount of coffee waste. However, according to feedback from 15 restaurants, the primary reason for coffee waste is the fear of coffee shortages, leading to overproduction and ultimately to waste. This concern has been identified in other studies as a contributing factor to food waste generation (e.g. Malefors et al., 2021; Steen et al., 2018). Six of the restaurants reported that they do not have time to analyse customer flows, finding it more convenient to brew full batches instead. Adding to the complexity, particularly in Sweden, is the cultural expectation that a coffee purchase often includes the option for one or more refills. This tradition makes it difficult for coffee-serving establishments to predict demand with accuracy, as highlighted by one of the interviewees. However, it may be possible to utilise forecasting methods to address this issue. By integrating point-of-sale data from cash registers with records of actual coffee consumption, restaurants could more accurately predict the amount of coffee to brew each day. This approach would be most advantageous if it also encompassed other types of food, thereby offering a cost-effective solution for reducing waste.

Ten of the participating restaurants indicated that their waste reduction efforts are primarily motivated by the prospect of cost savings. However, only six of these establishments engaged in actual waste quantification to gain a clear understanding of their specific cases, and four reported that their future quantification efforts would be prompted mainly by demand from external sources. Participants in the quantification study reported that they chose to participate out of interest in the subject. However, only one restaurant planned to continue quantifying coffee waste, whereas the others found the process too time-consuming, despite acknowledging that the quantification method was relatively simple. This disconnect between expressed interest in waste reduction and actual commitment to ongoing quantification aligns well with findings by Filimonau and Coteau (2019) that managers' willingness to engage in food waste reduction is influenced by their perceived value of such activities. In this study, the restaurants' interest might not be considered strong enough to justify the time investment required for quantification. Similarly, the potential cost savings that could motivate waste quantification did not seem to outweigh the effort involved. This trade-off has also been observed in other parts of the food supply chain (Pietrangeli et al., 2023)

Extrapolating the findings to national scale underlined the significance of selecting appropriate distribution for data fitting, which can significantly influence the scaling results. In our case, one distribution's extrapolated outcome was 11.5% higher than the others. Instances where restaurants reported no waste (a total of six days) were omitted from the data fitting. In the simulations, however, the occurrence of zero-waste events was factored in as a proportion to generate realistic simulation outcomes. A broader dataset with more restaurants participating in waste quantification would offer a more comprehensive understanding of the situation. The conclusion that liquid coffee waste represents 21% of restaurant food waste is in line with findings by e.g. Ahmed et al. (2018) that around 19% of total waste consists of post-consumer liquid waste (beverages and soups). However, this is much higher than the level reported by Sehnem et al. (2022), who estimated that 4% of total food waste comes from drinks or desserts, and by Filimonau et al. (2019), who concluded that 4-19% of the food waste in coffee shops comes from coffee grounds. However, both those studies used survey methodology, potentially underestimating waste levels.

If this study had encompassed the entire liquid food waste stream, the results might have differed. Food service establishments might be more incentivised to participate in liquid food waste mitigation if it included a broader range of beverages, thereby making prevention efforts more impactful in overall reduction of food waste. However, studies on other parts of the food supply chain have suggested that coffee and tea are the main fractions to consider in liquid waste estimation

surveys (Swedish Environmental Protection Agency, 2021; Van Dooren et al., 2019). If liquid waste would be quantified with the same level of efforts that is used to quantify solid waste, the overall food waste statistics would potentially look very different from today where liquid waste is normally overlooked and therefore appear to not be a problematic loss of resources.

For waste quantification to take place, the process needs to be simple and ideally automatic (Malefors et al., 2024), but the costs of such automation is currently higher than the potential savings (Goossens et al., 2022), at least when it comes to liquid waste. Similarly, Filimonau and Coteau (2019) concluded that applying evidence-based forecasts for guest attendance and training teams could achieve waste reductions, but would involve high initial cost and uncertain overall gains.

The interview responses indicated that restaurant staff and customers view coffee as having low economic value, as reflected in the business model of including coffee in lunch menus and providing free refills. This creates highly variable demand and a high expectation that enough coffee will be available, barriers that are difficult to overcome even though coffee waste has an economic cost and a non-negligible environmental impact (Eneroth et al., 2022). It will be difficult for policymakers to address coffee waste specifically and, as long as the price of resources such as coffee is low in comparison to staff costs, there is a high risk that coffee waste will not be prioritised. Policymakers have the power to shift the cost balance for businesses by putting higher taxes on resource outtake rather than on staff. The first step is to investigate the scope of the problem and establish the necessary knowledge base for policymakers. Under current EU regulations, waste of beverages such as coffee can be voluntarily quantified and reported (European Commission, 2019). Considering the considerable amount of coffee waste generated annually, including liquid food waste in national waste statistics in Sweden and other countries can be a simple approach by policymakers to address the problem of coffee waste in restaurants.

5. Conclusions

This study found that on average, 10% of coffee brewed daily in Swedish restaurants is wasted (excluding coffee grounds and coffee left in cups). This corresponds to 3.3 kg of coffee waste per day, 13 g per guest per day and 730 g per employee per day. However, there was high daily variation, with coffee waste level ranging from 0% to 40% of brewed coffee. Waste was mainly due to concerns about coffee shortages, leading to overproduction of coffee, according to interviews with restaurant staff. According to most of the surveyed or interviewed employees, cost saving was the main driver of quantification, while lack of time was the main barrier to quantification.

Upscaling the findings to national level revealed that Swedish restaurants generate 17,800 tonnes coffee per year. This highlights the importance of including liquid waste in national statistics and of designing policies to counteract this sustainability issue.

CRediT authorship contribution statement

Christopher Malefors: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Rosa Hellman:** Writing – review & editing, Writing – original draft, Validation, Data curation, Conceptualization. **Amanda Sjölund:** Writing – review & editing, Writing – original draft. **Mattias Eriksson:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.resconrec.2024.107853.

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