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Trimming the Plate: A Comprehensive Case Study on Effective Food Waste Reduction Strategies in Corporate Canteens

Lia Orr * and Yanne Goossens

Johann Heinrich von Thünen-Institut, 38116 Braunschweig, Germany; yanne.goossens@thuenen.de
* Correspondence: lia.orr@thuenen.de

Abstract: This case study analyses food waste reduction measures in a corporate canteen, addressing environmental, economic, and social sustainability dimensions. By implementing seven actions such as raising awareness among kitchen staff, providing smaller portions and preparing soup from overproduction, food waste was reduced by 46% in two canteens serving up to 1800 people daily over the time period of six months. This preserved 343 kg of food waste, conserving over 450,000 kcal in nutritional value and yielding net economic savings of over 15,500 Euros, as well as environmental savings of over 31 tonnes CO_2 eq. and 213 mPt PEF. The Benefit-to-Cost Ratio (BCR) of 0.03 kg of food waste saved per 1 Euro invested, along with the associated savings of 40.78 kcal, 2.74 kg CO_2 eq., 0.02 mPt PEF, and 2.37 Euros, exemplifies the overall success of these actions. Therefore, this business case offers valuable insights into how (corporate) canteens can enhance sustainability and resource conservation by reducing food waste.

Keywords: corporate canteens; food service; food waste reduction; monitoring; resource efficiency; sustainable assessment

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1. Introduction

Food waste has emerged as a critical global challenge with far-reaching implications for the environment, economy, and social welfare. The Food and Agriculture Organization (FAO) estimates that approximately one-third of all food produced for human consumption is lost or wasted at a global scale [1]. This wastage not only strains valuable natural resources but also contributes to greenhouse gas emissions, exacerbating climate change concerns. The economic value of food waste is estimated to be worth billions of dollars each year, impacting not only businesses but also the global economy [2]. As societies grapple with the ethical dilemma of disposing food and its resources while millions go hungry, businesses have an integral role to play in addressing this issue. For the reporting year 2015, Schmidt et al. [3] reported a total food waste quantity of over 11 million tons for Germany. Restaurants and catering services contributed 1.69 million tons, accounting for 14% of this total. In the food service industry, particularly canteens and cafeterias, the facilities cater to the culinary needs of a large number of guests, often facing challenges such as unpredictable demand and the need to maintain customer satisfaction.

To advance national efforts in reducing food waste, the German Federal Ministry of Food and Agriculture introduced the National Strategy to Reduce Food Waste in 2019. As part of this initiative, discussion forums were established for all sectors along the food chain (primary production, processing, wholesale and retail, food service and private households) [4]. The discussion forum for food service was successfully concluded with the signing of a voluntary agreement in 2021. In this agreement the German Federal Ministry of Food and Agriculture together with associations from the German food service sector, committed to reducing food waste in the food service sector by 30% by 2025 and by 50% by 2030 [5]. Companies in the food service sector can join the voluntary agreement through a participation declaration, obligating them to implement specified minimum

requirements and reduction measures. Since early 2022, the Centre of Excellence for Food Service (CoE) has been responsible for implementing the voluntary agreement, in particular the declaration of participation. It is led by the association United Against Waste, with scientific guidance from the Thünen Institute.

1.1. Background

The food service sector is a heterogeneous sector composed of individual catering and communal catering [6]. These segments differ in terms of operations, service format, and guest structure. Individual catering is accessible to the general public and serves a changing clientele of individuals. Consequently, the food offerings are tailored accordingly. Communal catering, on the other hand, serves a consistent group of individuals. The food offerings are adjusted to the respective group and either change daily or rotate in a specific rhythm [7].

Individual catering encompasses both individual gastronomy and system gastronomy [6]. Examples of individual gastronomy include restaurants [7]. System gastronomy, such as a fast food chain, is defined by a clear concept that emphasizes centralized control, standardization of processes, and multiplication [8]. Communal catering is divided into various sectors including business, such as company canteens, care, education, welfare, as well as others [6]. In addition, there are various methods of presentation in food service: buffet, counter service, table service, and tray service; hybrid forms are also possible. This significantly affects the operational processes within each establishment and consequently influences the selection of waste reduction measures [9]. Furthermore, the guest clientele in food service varies greatly, and food service establishments must tailor their offerings to the specific target audience, each with distinct preferences for portion sizes, nutrients, ambiance, timing, taste, and more.

With its diverse offerings, food service is a growing sector and the second-largest consumer of food in Germany [10].

Food waste sources in the food service sector can be split into four areas. Food waste can arise at the storage level, for example during food planning, shopping and delivery. For instance, through misplaced orders, interrupted cold chains or misleading factors, taken into account while ordering such as wrong weather assumptions or inadequate information on how many guests can be expected [11]. Food waste can also arise at the production level through mistakes in production [12] or shortcomings in hygiene [13]. It also includes the discarding of by-products like potato peels during the cooking process. Overproduce is another area of food waste. This can arise through generous calculation of amounts, a fixed menu, planning, or missing time and space for further processing [14]. Plate leftovers are the last area of food waste. This can occur due to the taste, the amount, the lack of room for specific adjustments, and missing opportunities to take left over food home. This is only a short overview of factors in general leading to food waste in the food service sector to visualize the four areas in which food waste occurs; a more comprehensive overview can be found in Kuntscher et al. [9].

1.2. Research Gap and Objectives

The present paper was written within the context of the CoE in partnership with a company that volunteered to undergo an assessment of the sustainability of their actions with regard to food waste. Our primary objective is to offer a comprehensive assessment that extends beyond merely quantifying food waste reductions. This broader perspective is notably absent in existing literature [15] but is increasingly demanded, as underscored by the study conducted by Goossens et al. [16]. Our aim is to present not only the substantial food waste savings achievable through the implied measures but also to illuminate the benefits within the three sustainable dimensions (environmental, economic, and social). We aim to provide tangible insights for businesses, granting them a deeper understanding of how embracing food waste reduction can elevate their overall resource efficiency. Therefore,

our intention is to demonstrate in concrete terms the potential for cost savings, minimized environmental impact, and potential social implications.

Through this case study that centers on a corporate canteen's efforts to tackle food waste, we seek to identify best practices, lessons learned, and recommendations that can be applied to other similar contexts. Additionally, many businesses are adopting sustainability goals and corporate social responsibility initiatives. Minimizing food waste aligns with these objectives, demonstrating a commitment to environmental stewardship and ethical considerations [17]. Research in this area can provide evidence-based approaches for businesses looking to incorporate food waste reduction into their sustainability strategies.

The case study as well as the methods used for the sustainable assessment are described in Section 2 while Section 3 provides results and discussion differentiated in the monitoring of results and the assessment of sustainability. Finally, Section 4 provides a brief conclusion.

2. Material and Methods

2.1. Case Study Description

The case study was conducted within the framework of the CoE in collaboration with a healthcare company, focusing on their staff food service offerings. The case study was performed in a company that employs approximately 4000 people. The company has claimed it wants to be climate neutral by 2040. Our case study concentrates on the two employee canteens, open from 11:30 to 13:30 daily; subsequently, named Canteen A and Canteen B. The canteens are able to give food to up to approximately 2000 people daily. The food options are cooked at the campus itself by an external caterer. This caterer has committed to producing meals that are as seasonal, regional and sustainable as possible. For this, they state different strategies on their website, such as (A) a nose-to-tail concept using as much of the food as possible. It emphasizes the utilization of not only popular and prime cuts, such as fillet or sirloin steak, but also less commonly consumed parts like brains, feet, and stomach. The concept aims to minimize waste by incorporating these 'lesser-known' parts into culinary dishes, highlighting their unique flavors and ensuring a more sustainable use of the animal. This practice aligns with the ethos of reducing food waste by maximizing the use of all edible parts of an animal in cooking. (B) A motto week for climate actions to stress the relevance as well as (C) the claim to having used the excess food and waste in the best possible way.

The two canteens have quite different concepts, offer different food ranges and also have different interiors. Canteen A delivers a typical canteen food with different menu lines including German canteen classics such as Schnitzel with fries. The food is divided into portions on demand. Canteen B was refurbished a few years ago following the vision of future-oriented fresh cuisine. This is implemented through the use of three separate counters, each of which follows an all-in-one theme, where the food is cooked in front of the guests, which also enables the consideration of specialized guest wishes. One of the food counters, open only Tuesday to Thursday, has a nose-to-tail concept, which means that as much as possible from the food produce is used within one dish.

2.2. Food Waste and Food Waste Measures Implemented in the Canteens

In both canteens, the food waste measurement was implemented directly by the kitchen staff. At storage level, food waste was weighed before it was thrown in the bin. At production level, food waste could not be measured. At the level of overproduction, the food left over from the day was weighed and then put on a trolley which was moved to the fridge. The next day, this trolley was checked for possibilities of reuse in new dishes. This pattern of measurement created an exaggerated assessment of the overproduction area, as some of the measured overproduction does not actually end up in the bin, but is reused, and therefore should not be called food waste. Unfortunately, it was not possible to estimate the amount that is reused, as it varied very much from day to day. Plate leftovers were measured just before dishwashing, as the food left over on the plate was scraped

down into a bin, which was then weighed at the end of the day. The measured values were written down on a paper list which hung directly in the kitchen. The head of catering transferred these data to the digital software daily. For the monitoring tool, an external service provider was used. Both provided an overview with Key Performance Indicators (KPIs) such as time-bound food waste on the landing page. The food waste measurement did not easily allow a differentiation between the various food categories. For this case study, a half-year measuring period from November 2022 to April 2023 was looked at.

During the monitoring period, the two canteens implemented the same seven actions to reduce food waste. As shown in Table 1, all the food waste areas were tackled, but it must be pointed out that the plate leftovers were stressed within the implied measures. Action one was to create awareness of food waste amounts and their effects among the kitchen staff. This included the implementation of food waste monitoring. This action directly affects the occurrence within storage and production areas of food waste, as well as overproduction [17]. Action two was the offer of half portions, alongside the normal portions. This aimed at reducing plate leftovers, as consumers could decide which to choose according to the amount of hunger/time they had [18]. Action three was offering smaller plates at the salad buffet with no price changes. This can lead to a decrease in plate leftovers because less food is served whilst it still looks like a full plate [19,20]. Action four involved making a daily soup from the produce leftover from the day before. This reduces the amount of food waste created as overproduction [21]. Action five was aimed to reduce food waste from overproduction and plate leftovers. Reusable Mepal containers were bought and are available for customers based on an internal deposit system. This offers the possibility for them to take home food they were not able to finish home, but also makes it possible for guests to take away their lunch if, for example, they do not have the time to sit down at lunchtime [18]. Action six is the implementation of so-called "Waste Saver Special" which are meals that are offered at a reduced price at the end of serving time. This influences the amount of food waste left over in overproduction. Action seven involved direct communication with the guests about food waste and the value of food. This involved roll-up banners creating awareness of the effects of food waste, but also banners to nudge the guests towards options for reducing their own food waste [21,22].

Table 1. Overview of implemented actions and their effects on the four food waste areas (an X marks the direct influence).

Actions	Storage	Production	Overproduction	Plate Leftovers
1. Raising awareness among kitchen staff	X	X	X	
2. Half Portions Available				X
3. Small plates at the salad buffet				X
4. Daily soup made from food overproduced the day before			X	
5. Mepal containers for takeaway			X	X
6. "Waste Saver Specials": meal deals at the end of serving time			X	
7. Communication for greater awareness of food value				X

In total, one action directly influenced the area of storage and production, four actions directly influenced overproduction and four actions directly influenced plate leftovers.

The process commenced with an initial video call, facilitating a mutual understanding of expectations. This study examined a comprehensive bundle of measures that were implemented simultaneously. To gather relevant data, a multipronged approach was employed. This involved interviews with the Food & Beverage Head and Head of Catering, and on-site visits conducted by the authors. Based on the collected data, an Excel-based calculation model was developed, which was optimized and refined through collaborative insights from the company. Following the evaluation of all measures, the results were shared with the company via email prior to final publication.

2.3. Data Used

This study presents an integrated approach to assess the effectiveness and efficiency of food waste reduction measures in a corporate dining context. The company data that was collected for the present case study encompasses key variables such as food waste data, meal plans, and expert-derived estimates regarding the costs and benefits of the actions. Complementing this internal dataset, the Thünen Institute contributed data banks encompassing environmental impacts as well as nutritional information on food items, disposal, packaging materials, and marketing materials. By combining these datasets, a holistic assessment was achieved.

2.4. The Assessment Method

Goossens et al. [16] suggested a sustainability assessment framework to evaluate food waste prevention measures—a methodology is applied in this case study. In this, food waste prevention measures are evaluated on their food waste reduction potential and across the three dimensions of environmental, economic and social sustainability. The environmental and economic analysis is based on quantitative data of impacts and cost of the actual food that is prevented from being wasted, with associated disposal impacts/costs and the impacts/costs related to the implementation of the actions. Quantitative data for the social dimension is often missing. Therefore, the analysis is complemented with a qualitative assessment. The evaluation framework is constructed in line with the methodology proposed by the EU Joint Research Centre [23]. The ecological assessment is expressed through a carbon footprint (unit: CO_2 equivalents, CO_2 eq.) and an environmental footprint called the Product Environmental Footprint (PEF) (unit: milli-environmental points: mPt), calculated using the Agribalyse 3.1 database [24] and the Ecoinvent 3.9 database. Notably, the Product Environmental Footprint (PEF) amalgamates indicators across 16 environmental categories into a singular score, with the carbon footprint contributing to approximately 21% of the environmental footprint. Other categories encompass ionizing radiation, acidification, and eutrophication, hence a measure's impact on one category might be compensated by the changes it produces in others.

2.4.1. Meals Served in the Canteens

Before any steps are taken in the data analyses, it is important to prepare the data collected. To be able to obtain a deeper insight into the food categories wasted and therefore to be able to make more realistic assumptions on carbon and environmental impact, sales data in the form of menu plans and sales volume per menu line were collected. Every week, a unique meal plan is designed, and it includes various menu lines, each corresponding to a specific counter where the meals are served. For example, a menu line might be labelled as "Classics" and feature different meal options, such as "Schnitzel with fries" or "Spaghetti Bolognese". These menu lines are essentially categories that group together similar meal choices available for that week. For our data analysis, we compiled a dataset comprising a diverse range of meals served over 12 weeks. These 12 weeks were selected at random from various months in the year, including January, March, April, June, July, August, October, November, and December in 2022. This approach was adopted to ensure the dataset remained unbiased and representative of the full spectrum of meals served throughout the year.

In the initial phase, we identified the various components presented in each menu option and assigned specific quantities to each component. These quantities were estimated by the (catering) company, providing insights into the approximate portion sizes for each component typically found on the plate. The correlating CIQUAL code was determined using the ANSES-CIQUAL nutritional database and the Agribalyse database [24,25]. This CIQUAL code represents a unique code given to each food item, allowing LCA practitioners to easily extract both environmental and nutritional information from these databases. The environmental footprint and carbon impact were then calculated for each meal by weighting the component's influence on each meal. From that result, the environmental impact as

well as the nutritional value for each menu line in the two canteens was then calculated. Adding sales data for the different menu lines made it possible to calculate the average impact for each of the canteens and a total average for both canteens (see Figure 1).

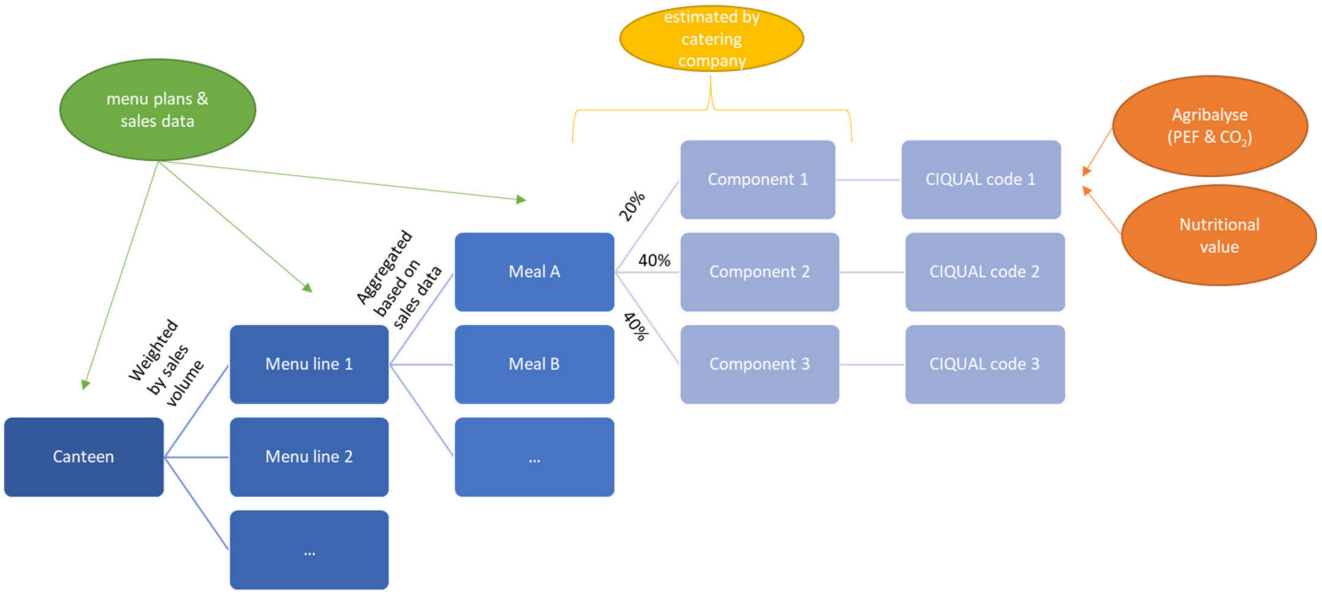

Figure 1. Data used for the calculation of nutritional, carbon and environmental impact, resulting in an average for the case study.

The resulting average for each of the canteens (for the nutritional value, the carbon footprint and the environmental footprint) was then used to assess the impact of the food waste in the following steps. An assumption has been made that the food component share in the sales volume is the same as in the food waste, which is the best possible assumption, due to the scarcity of available data.

2.4.2. Quantitative Assessment of the Food Waste Reduction Measures

The quantitative assessment consists of the following four steps:

Step 1. Effectiveness Assessment: To evaluate the effectiveness of the implemented measures, a comparative analysis was conducted between the initial and final food waste quantities. This process entailed quantifying the collective reduction achieved as a direct result of the implemented interventions. This was performed with the food waste monitoring data delivered by the company for a half-year period (November 2022 till April 2023). In our next step, based on the food waste monitoring data, we show how much food waste is being generated in each canteen on a per-meal basis, and how this evolves during the course of our monitoring period. The use of grams of food waste per meal as the unit of measurement allows for better comparability within the sector, with an assumption that an average meal contains 450 g.

Step 2. Resource Efficiency Computation: A comprehensive cost–benefit analysis across the economic, environmental, and social dimensions of sustainability was carried out. All quantifiable effects emanating from measure implementation are factored in as "inputs" and "outputs"—encompassing expenses, labor efforts, material and equipment usage, as well as packaging. The costs and impacts needed to execute the seven actions implemented to reduce food waste are shown in the following paragraph.

Implementation and execution of the various actions implied different specific costs and savings:

Action one, creating awareness among food staff, includes the measurement of food waste. This resulted in the following costs: 100 Euros per month for the external software recording food waste, 10 meetings that were each 1.5 h long and included two people for

the development of an in-house software solution, five minutes per day to submit the data and a monthly meeting, again half an hour long, for two people to discuss the food waste results. The labor costs were hereby set at 30 Euros per hour for in-house development and 15 Euros per hour for kitchen staff.

Action two involved introducing half-sized portions to the menus. These smaller portions use only half the amount of ingredients compared to regular-sized servings and came with a 30% price reduction. There was a loss in profit of 0.85 Euros per meal. Approximately five per cent of total daily servings were half-sized portions, resulting in a daily reduction in profit margin of approximately 50 Euros. It did not change the cashier process, there was no additional kitchenware needed, and it did not change processes for the kitchen staff. One movable plastic display was purchased with the costs of 6 Euros. The portable display needs to be replaced approximately every six months due to its limited durability and frequent breakages.

Action three, introducing smaller plates at the salad buffet, resulted in no additional expenses since these smaller plates were already available within the company and did not have to be bought. The profit margin for the smaller plates remains unchanged, since the pricing has been adjusted to align with the underlying costs.

Action four was a daily soup made with food from overproduction. Prior to this change, two soups were prepared daily using fresh ingredients. By switching to a single soup made from leftovers, the kitchen staff saved approximately five minutes of work per day. Additionally, they were able to save on fresh ingredients, which were estimated to be approximately 21 kg per day with a monetary value of 80 Euros per day.

For Action five, the use of reusable Mepal containers for take-away, the resulting changes with a cashier process or dishwashing process were expected to be negligible, as these were operations commonly performed within the kitchen. Nevertheless, the containers were purchased at a cost of approximately 6 Euros per unit prior to the implementation. The company acquired 750 square-shaped and 750 round-shaped containers. It was estimated by the experts that these containers could withstand up to 300 uses, which is equivalent to a durability of approximately five years. Additionally, a roll up banner and stand at the cost of 70 Euros was purchased. These roll-ups are made of PVC, and their expected durability is approximately two years before they may require redesign or show signs of wear and tear.

Action six, known as the "Waste Saver Specials," refers to a special offer, available at the end of service time for a reduced price. As this special represents approximately 1% of daily purchases, it results in a daily loss of profit margin amounting to approximately 3 Euros. For action six, another roll-up was purchased.

Action seven, the communication for greater food value, involved the purchase of six roll-up banners.

On a social level, we looked at how the measures affected jobs (in terms of jobs lost or created) or donations. Social aspects, which could not be quantified, are further elaborated in Section 3.3.

Within each canteen, the food waste reduction that was achieved led to significant reductions in environmental impacts and costs. This was achieved by minimizing food produce needed (some of which would then be wasted) and decreasing the amounts of waste going to disposal. All of these count as "outputs" in our assessment. Waste is disposed of in a biogas plant 30 km away from the company. The costs per ton of food were estimated at 20 Euros per ton; associated environmental impacts were taken from literature. Multiplying the per ton disposal impacts and costs with the food waste savings that were achieved during the six-month monitoring period, gives the result in the total savings associated with the avoided food waste disposal. Similarly, the avoided impacts and costs associated with no longer having to produce (and prepare) the food that no longer goes to waste was calculated. The costs of the meals were provided by the company and only include procurement costs for the meal components, as other data related to, for example, labor time or energy costs associated with the preparation of the meals could not

be acquired. Reducing plate leftovers subsequently led to a five-minute time reduction daily for dishwasher operation. Associated environmental impacts for the avoided food waste were calculated using the Agribalyse database, as explained in Section 2.4.1.

Results in the net environmental and economic benefits associated with the implementation of the bundle of measures in the two canteens are achieved by subtracting the two outputs from the (net) inputs directly associated with the implementation of the seven measures.

Step 3. Nutritional assessment: Transitioning to the third stage, the food waste reduction computed in the initial phase is translated into nutritional value savings (kilocalories). Employing the CIQUAL database, pertinent nutritional values were acquired.

Step 4. Results Consolidation: In the final stage, benefit–cost ratios are determined, functioning as efficiency metrics (Key Performance Indicators, KPIs) for the measure. These ratios show the food waste or kilocalories saved per Euro invested, as well as the economic, ecological, and social savings per Euro invested.

2.4.3. Qualitative Assessment of the Food Waste Reduction Measures

Qualitatively, our assessment was founded on three of the four indicators introduced by Wegner et al. (2020) [26]:

(a) Implementation effort, which measures the level of process improvement, staff training, and system adjustments necessary for implementation;
(b) Longevity, which assesses the potential for maintaining the implementation over an extended period;
(c) Transferability, which evaluates the feasibility of implementing the measure in different contexts or locations.

Notably, we did not include their indicator "Motivation" in our analysis due to the absence of insights from the employees responsible for implementing the measures.

For each of the implemented measures, the effects were rated with low, medium and high based on insights gained from the case study as well as interviews with the company experts.

3. Results and Discussion

3.1. Food Waste Savings

The implementation of waste reduction measures resulted in an overall reduction in food waste from 742 kg in November 2022 (subsequently named month 1) to 399 kg in April 2023 (subsequently month 6), thus resulting in food waste savings of 343 kg. The trend of reduction, however, is not linear, exhibiting some variation throughout the observed period. Figure 2 illustrates food waste quantities for canteens A and B in grams per meal over consecutive months. This chart highlights the contribution of different sources to food waste.

For Canteen A, the level of food waste per meal stood at 151 g/meal in month 1. This initial quantity increased to 166 g/meal by month 2. A significant reduction ensued in month 3, dropping to 47 g/meal. Following this pronounced decline, the rate of reduction stabilized, culminating in a final data point of 51 g/meal in month 6. This represents a total reduction of 66% over the course of six months. Examining the composition of food waste sources in terms of their mean distribution, storage accounts for hardly any (therefore not visible in Figure 2), plate leftovers contribute 65%, and overproduction constitutes 36% of the overall food waste. The plate leftovers are being reduced in a constant way, ranging from 108 g/meal in month 1 to 29 g/meal in month 6. The overproduction beginning at a value of 42 g/meal in month 1 decreased to 22 g/meal in month 6. The remarkable shift in month 3 could be attributed to changes in the food concept, aligning more closely with traditional canteen offerings, additionally Fridays the Canteen was then closed.

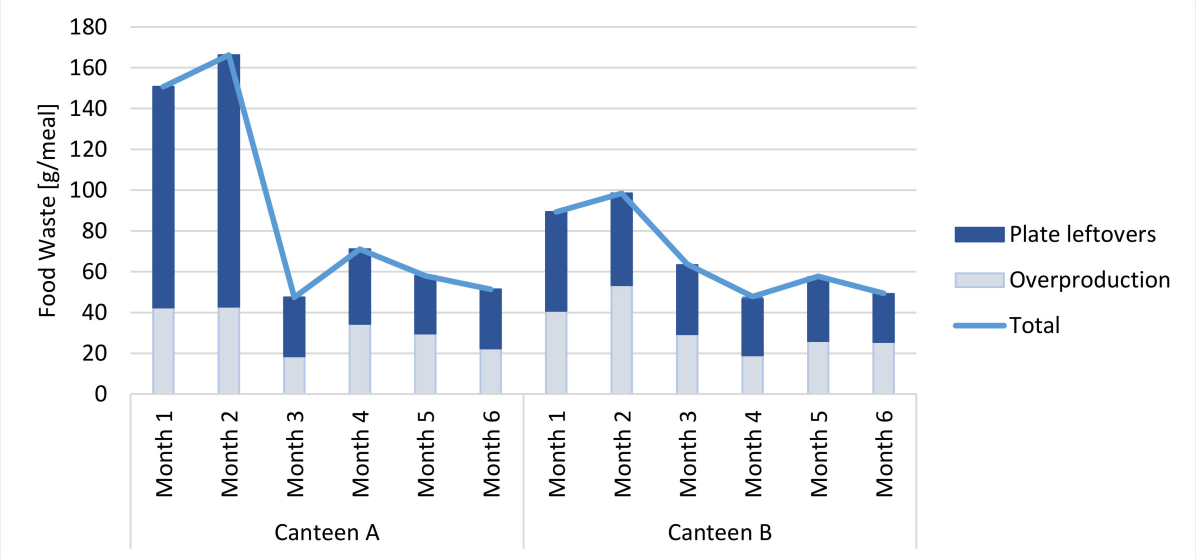

Figure 2. Food Waste for Canteen A and B in the six-month monitoring period, divided into food waste areas.

For Canteen B, the recorded food waste per meal stood at 89 g/meal in month 1. Over time, this quantity gradually decreased, reaching 49 g/meal in month 6, and resulting in a total decrease of 44%. Analyzing the composition of food waste sources in terms of their mean distribution, storage contributes 2%, plate returns account for 52%, and overproduction constitutes 42% of the total food waste. The plate leftovers decrease consistently from 48 g/meal in month 1 to 23 g/meal in month 6. The overproduction beginning at a value of 40 g/meal in month 1 decreased to 26 g/meal in month 6.

A comparative analysis of the two canteens reveals distinct patterns in their food waste reduction efforts. The first canteen, despite initially experiencing higher levels of food waste at the outset (151 g/meal in month 1), showcased a strong reduction. The second canteen started with a comparatively lower food waste level of 89 g/meal. While the reduction in food waste was less dramatic than the first canteen, it displayed a more consistent decline over the observed period. It was out of scope of this study to investigate why exactly the initial levels of food waste in Canteen A were a lot higher than in Canteen B. Most probably, this is due to differences in underlying concepts and approaches used in each canteen, such as the "cook in time" preparation applied in Canteen B versus a more classical buffet approach in Canteen A.

In comparison to the other corporate canteens from the CoE it must be said that our case study excludes food waste caused in production, which on average causes 25–55% of food waste within a food service business [27]. Borstel et al. [27] looked at a sample of 359 companies and reported an initial food waste quantity of 108 g/meal (incl. production food waste) at the beginning of the measurement period. In a second measurement period, the food waste was notably reduced to 75 g/meal. This translates to an overall reduction of 31% in food waste. While the study by Borstel et al. [27] presents valuable insights on food waste reduction at a broader scale, the variations in starting points, rate of reduction, and final outcomes observed between the individual canteens indicate that success in food waste reduction varies based on specific operational, contextual, and intervention factors. It is important to note that the data available for comparison in the field of food waste reduction is limited. These limitations arise from the diverse scopes and methodologies used across various studies, making direct comparisons challenging. We therefore see the need for a more harmonized and standardized approach to monitoring and assessing food waste reduction efforts in the food services sector. The development of common metrics and shared best practices could not only facilitate more comprehensive cross-study

comparisons but also lead to a deeper understanding of sustainable food waste reduction. This objective aligns precisely with the goals of the CoE.

3.2. Quantitative Sustainability Assessment of the Measures Implemented

In a span of six months, the company realized substantial progress through the seven implemented measures, managing to curtail food waste by 343 kg, equivalent to a caloric value of 476,075 kcal.

3.2.1. Nutritional and Environmental Characterization of the Meals Served within the Canteens

As described in Section 2.4.1 the nutritional and environmental impact was calculated for each meal and summarized for each menu line, resulting in an average impact for Canteen A and B which could then be used for the further assessment (see Table 2). For more detailed information, please refer to the Supplementary Material provided.

Table 2. Nutritional content, carbon footprint and environmental footprint of the meal lines offered at Canteens A and B, resulting in a case study average.

	Nutritional Value kcal/kg	**Carbon Footprint kg CO_2 eq./kg**	**Environmental Footprint mPT PEF/kg**
Canteen A	1383	3.02	0.41
Canteen B	1481	4.82	0.65
Average Canteens A and B	1425	3.79	0.51

3.2.2. Measure-Specific Environmental Impacts and Costs

Table 3 shows the environmental impacts and costs directly associated with the implementation of the seven measures. Zero values are given if no impacts or costs occurred (and thus do not refer to missing values). When it comes to the social effects, none of the measures led to the creation, nor to the loss, of jobs within the company. Furthermore, the measures did not affect donations. As such, the social inputs are equal to zero for all measures. For matters of clearness though, it was decided not to add a column of zeros to Table 3.

Table 3. Environmental and economic inputs directly associated with the seven implemented actions (measurement period of 6 months).

Action	**Ecological Assessment**		**Economic Assessment**
	Carbon Footprint kg CO_2 eq.	**Environmental Footprint mPt PEF**	**Costs Euro**
1. Raising awareness among kitchen staff	0.00	0.00	1837.50
2. Half Portions Available	0.02	0.002	6526.50
3. Small plates at the salad buffet	0.00	0.00	0.00
4. Daily soup made from food overproduced the day before	0.00	0.00	0.00
5. Mepal containers for takeaway	0.86	0.07	917.50
6. "Waste Saver Specials": meal deals at the end of serving time	0.66	0.06	1945.30
7. Communication for greater awareness of food value	0.66	0.06	105.00
Total Inputs	2.21	0.19	11,331.80

Two of the implemented actions did not create any costs (action three and four); this is also due to the fact that the canteens are run by quite a big external company that has a lot of possibilities at hand.

The most costly were the three measures: Half Portions Available (action two) as well as "Waste Saver Specials" (action six) caused high costs through lost profit margins. Raising awareness (action one) was very costly in terms of economic inputs, as it was combined in this case with the monitoring of food waste for which an external monitoring tool was used. Within the six-month monitoring period, the company created an in-house solution for this digital software, thereby reducing future costs for food waste monitoring.

Environmental impacts were created through the marketing materials and the Mepal containers (action two, five, six and seven).

The food waste reduction measures resulted in both environmental and cost savings. Introducing half-sized portions reduced the need for purchasing as much produce. We hereby note that these economic procurement savings were already included in the reduced profit margin calculations, and are thus already covered by the input value given in Table 3. Moreover, by using 90% of overproduction in the daily soup, fewer ingredients were required. Additionally, reducing food waste led to saved products and decreased expenses for disposal, while minimizing plate waste meant less time was spent on cleaning dishes. The outcomes of these savings are presented in Table 4.

Table 4. Environmental and economic outputs directly associated with the seven implemented actions and outputs associated with the food waste savings (measurement period of 6 months).

	Ecological Assessment		**Economic Assessment**
	Carbon Footprint kg CO_2 eq.	**Environmental Footprint mPt PEF**	**Costs Euro**
Outputs directly resulting from the implemented actions			
4. Daily soup made from food overproduced the day before	29,937.15	67.84	22,508.64
Outputs associated with the food waste savings			
Saved products	1075.24	144.52	2782.80
Saved waste disposal	41.39	1.08	6.86
Less plate leftovers = time savings in the kitchen	0.00	0.00	1575.00
Total Outputs	31,053.78	213.44	26,873.30

For more detailed information on the environmental and economic outputs of the seven implemented actions, please refer to the Supplementary Material provided.

3.2.3. Sustainability Assessment of the Measure Bundle

Subtracting the outputs in Table 4 from the inputs in Table 3 provides the results for the net environmental and economic benefits. From Table 5, it is clear that the bundle of measures achieved an environmental footprint reduction of 213 mPt PEF and a reduction of over 31 tonnes CO_2 eq. in the CO_2 footprint over the course of 6 months. The financial aspect also saw positive effects, with over 15,000 Euros saved. On a social level, there are no inputs or outputs (all equaled zero). The resulting net social benefits thus equal zero as well.

Table 5. Sustainability assessment of the measure bundle for the six-month period: net benefits and benefit-to-cost ratio.

	Mass	**Nutritional Value**	**Carbon Footprint**	**Environmental Footprint**	**Costs**	**Social Level**
Net Benefit	343 kg	462,151 kcal	31,052 kg CO_2 eq.	213 mPt PEF	15,542 Euro	0 Jobs or donations
Benefit-to-Cost Ratio (BCR)	0.03 kg/Euro	40.78 kcal/Euro	2.74 kg CO_2 eq./Euro	0.02 mPt PEF/Euro	2.37 EUR/Euro	0 Jobs or donations/Euro

Table 5 further shows the efficiency metric, the "benefit-to-cost ratio" for each indicator, which represents the savings per invested Euro. The higher the food waste savings, the more efficient the action (bundle) is in terms of financial investment. The same principle applies to the quantity of saved kilocalories, carbon footprint, environmental footprint as well as the cost ratio. For the seven actions implemented in the canteens, a positive outcome was achieved in all categories. For each invested Euro for the implementation of the actions, 0.03 kg of food with a nutritional value of 40.78 kcal could be saved. This has an impact of 2.74 CO_2 eq. and 0.02 mPt PEF on the environment. Overall, leading to a benefit-to-cost ratio of 2.37 Euros for each Euro invested.

3.3. Qualitative Sustainability Assessment

The implementation of food waste reduction measures has yielded positive impacts on various social aspects within the canteen operations that cannot be quantified. The engagement of the kitchen staff in the process of measure development and the shared vision of reducing food waste have contributed to an increased sense of job satisfaction and motivation among the staff.

Table 6 further shows how each of the measures perform for the implementation of the three qualitative indicators: effort, longevity and transferability.

Table 6. Qualitative Indicators for the implementation of the three qualitative indicators: 1. Effort, 2. Longevity and 3. Transferability of reduction actions (low, medium, high).

	Effort	**Longevity**	**Transferability**
1. Awareness raising among kitchen staff	High	Medium	High
2. Half Portions Available	Low	High	High
3. Small plates at the salad buffet	Low	High	High
4. Daily soup made from food overproduced the day before	Low	High	High
5. Mepal containers for takeaway	Medium	High	High
6. "Waste Saver Specials": meal deals at the end of serving time	Low	High	High
7. Communication for greater awareness of food value	Medium	High	High

Creating awareness among kitchen staff (action one) initially required additional work as they needed to adapt to incorporating the measurement of food waste into their daily routine. Moreover, acquiring and implementing a monitoring tool added to the workload. Consequently, this measure introduced a fixed daily time commitment, which might pose challenges for its continuous execution in the future. In contrast, half portions (action two), smaller plates at the salad buffet (action three), daily soup from overproduction (action four) were implemented with minimal effort in this particular canteen. Action five, involving Mepal containers, demanded a significant implementation effort, starting with a substantial initial investment and the creation of promotional materials such as roll-up banners. "Waste Saver Specials" (action six) were also implemented with minimal effort. The communication efforts to promote greater food value (action seven) also necessitated the production of engaging roll-ups.

However, it is important to note that introducing smaller plates for half portions or at the salad buffet in other canteens might require the purchase of additional plate sizes, potentially resulting in higher implementation efforts/costs in different contexts [20]. Overall, these measures exhibit a high degree of longevity, making them well-suited for potential replication in other (business) canteens.

We could not isolate the specific impact or efficiency of each individual action, since we assessed the combined effects of all actions as a whole.

3.4. Limitations of This Study

In our study, there were certain limitations that should be taken into account for future research. Firstly, while we measured food waste data in terms of total amounts, it would be beneficial for future studies to delve deeper, considering specific food products or, at

the very least, food categories. Additionally, focusing on the costs of individual food items rather than entire menus would provide a more detailed perspective. Moreover, our study lacked data on food waste generated in the production area, which is an important aspect to consider. It would also be valuable to collect data differentiating between reuse and waste in the area of overproduction to gain a more comprehensive understanding. To enhance the theoretical basis and strengthen our qualitative assessment, it would be advantageous to conduct staff interviews. Such interviews could provide valuable insights into the perspectives of the employees regarding the implemented measures and their perceived value. Similarly, conducting guest interviews could help assess changes in guest satisfaction resulting from food waste reduction measures.

When interpreting our results, several key considerations should be kept in mind. Firstly, our quantitative environmental assessment relied on the Agribalyse database, which represents environmental impacts in France. While it provided detailed impacts for many products, these assumptions may not be perfectly representative of the German context [28]. The quantitative assessment of food waste data was performed by the kitchen staff; the quality of the self-reported data may therefore be influenced due to individual errors. Additionally, the kitchen might have reported less waste than was actually reduced in order to improve the figures for their performance. In terms of social impact, our assessment was primarily qualitative, based on interviews with individuals. This approach may not necessarily yield completely objective opinions. Furthermore, the transferability of our findings depends on the framework at the starting point of measurement, including the process workflows and production volume. It is important to note that our study focused solely on the effects within the corporate canteen itself and did not extend to other steps in the value chain. Furthermore, in an ideal scenario, measures would be implemented sequentially with time in between to assess the effects of each measure. However, this can be highly impractical in the daily operations of canteens. As a result, we cannot single out the food waste saving potential of each individual measure, making it impossible to determine which measures would be the most effective. Lastly, during the data collection process, we were told by the company that many measures were implemented at no additional costs. This influences the results of the sustainability assessment strongly, whereas it might be possible that companies underestimate the occurring costs as these seem negligible (and therefore equal to zero) to them. Therefore, future studies should aim to collect more comprehensive cost data to refine their evaluations.

4. Conclusions

This case study, due to its comprehensive approach, offers valuable insights for corporate canteens seeking to reduce food waste. By considering not only food waste reduction but also assessing the influence on the three dimensions of sustainable assessment—environmental, economic, and social—it provides a holistic view of the impacts. Importantly, this study utilized the best available data, even if not perfectly tailored to the German context, to evaluate environmental and economic aspects. Furthermore, it is essential to note that the participating company voluntarily took part in this study, covering the costs for implementation, data collection, and collaboration with the Thünen Institute themselves. This voluntary participation highlights the practical relevance and commitment of businesses to address food waste and sustainability challenges in their corporate canteens, making the insights gained from this study particularly relevant and valuable for similar settings.

In conclusion, over the course of a six-month measurement period, the implementation of seven actions led to a reduction of 46% in food waste, amounting to 343 kg. This reduction is equivalent to preserving over 450,000 kcal of nutritional value. The most resource-intensive measure was Half Portions Available (action 2), through reducing the profit margin majorly. Also, through a reduced profit margin, "Waste saver specials" (action six) were costly. Awareness raising (action one) was also rather costly, it included implementing a food waste monitoring program involving the use of an external monitoring tool, necessitating financial resources. However, during the six-month monitoring period,

the company developed an in-house solution for this software problem, which is expected to reduce the cost of future food waste monitoring. Additionally, the availability of half portions (action two), caused notable expenses, primarily due to its impact on profit margins. On the other hand, some of these resource-intensive measures also resulted in considerable resource savings. This is the case for example for actions 2 and 4, where considerable procurement savings could be achieved.

As our assessment considered the collective food waste reduction effect of all implemented measures, we refrain from singling out a particular action as the most effective or efficient. Over the time period of six months in two canteens serving up to 1800 people daily, the following results could be achieved. Despite the total implementation costs of over 11,000 Euros, these actions resulted in substantial savings, totaling nearly 27,000 Euros. Balancing outputs and inputs, this results in net economic and environmental benefits of over 15 thousand Euros, over 31 tonnes of CO_2 eq. and 213 mPt PEF. This translates to a Benefit–Cost Ratio (BCR) of 0.03 kg of food waste saved, which corresponds to conserving 40.78 kcal, reducing greenhouse gas emissions by 2.74 kg CO_2 eq, sparing 0.02 mPt PEF, and saving 2.37 Euros for every 1 Euro invested. In conclusion, while some actions required initial adjustments and investments, they have demonstrated longevity and are suitable for replication in other (business) canteens.

For future research the authors suggest deeper food waste analysis, emphasized subjective social impact assessments through interviews with staff and guests, and highlight the need for comprehensive cost data.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16020785/s1, Table S1: Nutritional content, carbon footprint and environmental footprint of the meal lines offered at Canteens A and B, resulting in a case study average; Table S2: Detailed net environmental and economic inputs and outputs directly associated with the seven implemented actions (measurement period of 6 months).

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