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Research paper

Reducing food waste in hotel kitchens based on self-reported data

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ABSTRACT

This study provides insights into the effects of self-reporting on food waste generated in hotel kitchens, and its potential for reducing waste. As a case study, we focus on the generation of breakfast buffet leftovers in four hotels in Germany. To facilitate the self-reporting, we developed a food waste tracking system, which was operated by staff members of the pilot kitchens over 12 months. The self-reporting intervention contributed to improving operational kitchen processes such as refilling the breakfast buffet with less food prepared just-in-time, particularly during the last 30 min of the breakfast time. The self-reported quantities decreased during the first five months of the investigation period and then remained almost constant at a relatively low level. Breakfast buffet leftovers were reduced on average by more than 64.3% of mass, which correlates to annual monetary savings of approximately EUR 9000 per kitchen. The findings of our study demonstrated that breakfast buffet leftovers can be reduced significantly by simple changes and small improvements in daily kitchen routines. However, further research is needed to assess whether self-reporting interventions also contribute to reducing food waste for other types of buffets and food services.

1. Introduction

The United Nations formulated food waste reduction targets within the Sustainable Development Goal 12.3, which aims to halve global food waste by 2030 at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses (United Nations, 2015). Current extrapolations of food waste quantities in Europe are estimated at approximately 88 (±14) million tons (Stenmarck et al., 2016). These food waste quantities cause nearly 15–16% of the environmental impact of the food supply chain and correspond to approximately 186 million tons of CO_2 equivalents per year (Scherhaufer et al., 2018). Given that most food waste in Europe is generated at consumer level, reduction measures in the food service sector can provide an important contribution to achieve parts of the Sustainable Development Goal 12.3 (Beretta & Hellweg, 2019).

1.1. Food waste in the hospitality sector

The German food service sector produces approximately 1.69 million tons of food waste per year, of which approximately 1.22 million tons could be avoided. Specifically, the hospitality sector in Germany generates an average quantity of approximately 80,000 tons of food waste per year, which corresponds to 136 g of wasted food per meal (Schmidt et al., 2019). Food waste in gastronomy particularly occurs during processes such as food storage, preparation of meals, serving and consumption. Accordingly, the literature has often distinguished food waste into several categories, namely *storage waste*, *preparation waste*, *leftovers* from serving dishes at buffets and *plate waste* (Engström & Carlsson-Kanyama, 2004; Møller et al., 2014; WRAP, 2013). Von Borstel et al. (2017) showed that most food waste in the German hospitality sector is generated by buffet leftovers (45%), followed by plate waste (30%), preparation waste (20%), and storage losses (5%). Recent literature has confirmed that buffet leftovers and overproduction can be avoided to a large extent, resulting in high savings potential (Okumus, 2019; Papargyropoulou et al., 2016; Silvennoinen et al., 2015).

1.2. Influences on food waste generation

There are several factors and situation variables that influence the production of food waste in gastronomic kitchens (Göbel, 2018). The literature has named a few of these variables, of which some relate to the internal management of the kitchen, including professional skills and experience of the staff, and others refer to communication structures between the kitchen administration, suppliers, customers and staff members (Heikkilä et al., 2016). However, some variables, such as the number of guests, are external and may therefore be more difficult to control. For instance, food waste increases when a high number of guests unexpectedly miss the event (Gu, 2014; Hennchen, 2019). Menu

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planning requires not only estimates of the food demand with regard to guest numbers, but also accurate product inventory and a precise organization and arrangement of the ingredients for the food preparation (Silvennoinen et al., 2015). We can deduce that proposed measures to reduce food waste range from changes that require little effort, such as using smaller serving spoons, to more elaborate approaches, such as regular staff training (Marthinsen et al., 2012). There is indeed a certain complexity in identifying and implementing reduction measures due to the variety of influential factors. Recommendations for improvements are therefore often limited to boundary conditions of case specific studies and can rarely be generalized, emphasizing the need for gastronomic kitchens to conduct individual measuring and self-reporting practices.

1.3. Measuring as a food waste reduction measure

According to literature, a fundamental part of an effective intervention is to measure and monitor food waste. In this manner, adequate actions for prevention can be deduced and the performance of prevention measures can be controlled (Heikkilä et al., 2016; Silvennoinen et al., 2015). Eriksson et al. (2017) recommend a detailed waste quantification within each kitchen due to the individuality of reasons for food waste, which can result in different opportunities to reduce it. Waste analytics provide a high content of information because it follows the process of weighing the discarded food directly at the source of origin (Waskow et al., 2016). The data thus collected support further optimization of food management and facilitate the related planning and preparation processes. Food waste tracking systems that support gastronomic kitchens to quantify food waste are offered by enterprises from the United States such as *Leanpath* or Europe such as *Winnow Solutions, Kitro, eSmiley, Matomatic,* and *Visma* (eSmiley, 2020; KITRO, 2019; Leanpath, 2019; Matomatic, 2020; Visma, 2020; Winnow Solutions Limited, 2019). The basic functions of these tracking tools are similar and differ mainly with regard to associated consulting services such as employee training or individualized development of measures. Further differences refer to optional functions, such as visual photo capture and artificial intelligence technology for the automatic identification of the food waste items.

1.4. The potential of self-reporting

The implementation of measuring devices in kitchen routines requires an additional self-reporting task because the kitchen staff weighs and documents the wasted quantities. Self-reporting processes, in general, are related to awareness raising and cause adaptive reactions that result in behavioral changes (Zimmerman, 2002). Empirical research in households has already confirmed that substantial reductions of food waste can be achieved within self-reporting processes (Comber & Thieme, 2013; Leverenz et al., 2019; Thieme et al., 2012). The use of the aforementioned digital scales can also be expected to raise awareness amongst kitchen staff because they provide information directly to the operator, which could trigger individual behavioral changes.

As described thus far, the literature has generated knowledge on food waste to a considerable extent and showed the benefits of self-reporting interventions. Furthermore, case studies have demonstrated that the reduction potential in the hospitality sector is high and confirmed the feasibility of reducing food waste in general. By contrast, the literature has rarely examined in-depth measures and practical interventions over long periods of time. Such approaches would generate more complete information on the effectiveness of measures to provide stakeholders with incentives to reduce food waste (Goossens et al., 2019). Our study contributes to fill this research gap by presenting insights from food waste quantification within a self-reporting intervention in hotel kitchens. Thus, our approach follows the recommendation of Stöckli et al. (2018) in testing measures to prevent food waste in cooperation with practical and academic contributors.

1.5. Objectives

With this study, we aimed to quantify breakfast buffet leftovers using a food waste tracking system. The main objective of this paper is to assess whether the self-reporting in hotel kitchens can lead to food waste reductions at the breakfast buffet. To answer this research question, the following hypotheses are tested:

$H_{0:}$. Self-reporting of breakfast buffet leftovers has no effect on food waste quantities.

$H_{2:}$. Self-reporting of breakfast buffet leftovers leads to food waste reductions.

To investigate the savings potential, we estimated the monetary effects associated with the generation of breakfast buffet leftovers. Furthermore, we aimed to determine the influence of guest numbers on the breakfast buffet leftovers to gain insights into the relevance of this factor within the self-reporting intervention.

2. Material and methods

2.1. Methods and study design

This investigation focuses on quantifying and analyzing breakfast buffet leftovers in hotel kitchens. Our case study investigates a self-reporting intervention in four kitchens of the same hotel group, where the kitchen crew weighed and documented the breakfast buffet leftovers. To integrate the self-reporting process into the daily kitchen routine, we developed a food waste tracking system named *RESOURCEMANAGER FOOD.* The tracking system contains software installed on a standalone computer, which is connected through a USB port to an electronic scale. The user interface of the software is similar to a smartphone application and enables quick handling and an easy operation mode. To ensure harmonized reporting for the subsequent analyses, the products were aggregated into the following product categories: *bakery products*, *dairy products*, *fruits*, *vegetables*, *cheese*, *warm dishes*, *fish*, *cold meat,* and *others*. Individual photos of the food items and serving dishes were integrated into the software to facilitate the navigation through the user interface (Fig. 1).

The leftovers were weighed within the same standardized serving dishes in which they have been presented to the guests at the buffet. The tare weight of each serving dish was stored in the program, which means that the net weight of the wasted food was directly measured and saved in the database. The tracking system provided a real-time graphical visualization of the measured data in the form of horizontal bar charts. Thus, the program provided a direct feedback and immediate information on breakfast buffet leftovers to the operators, namely the kitchen staff. Sample photos of breakfast buffet leftovers and the weighing procedure using the developed food waste tracking system are presented in Fig. 2.

2.2. Sample characteristics

The pilot kitchens are part of the hotel group *Maritim Hotelgesellschaft mbH*, which is rated with four stars according to the classification of *Hotelstars Union* (Hotelstars Union, 2015). The four hotels are located in different German states and spread across southern, eastern, and northern Germany. The hotels are indexed as Hotels A, B, C, and D in the remainder of this paper. We analyzed the breakfast buffet leftovers based on the daily self-reported quantities. The measurements were conducted over a period of 336 days (12 months) and started at different time horizons for each hotel, in 2014 and 2015 (Table 1). The breakfast buffet was accessible from 6.30 a.m. until 10.30 a.m. for hotel guests seven days a week.

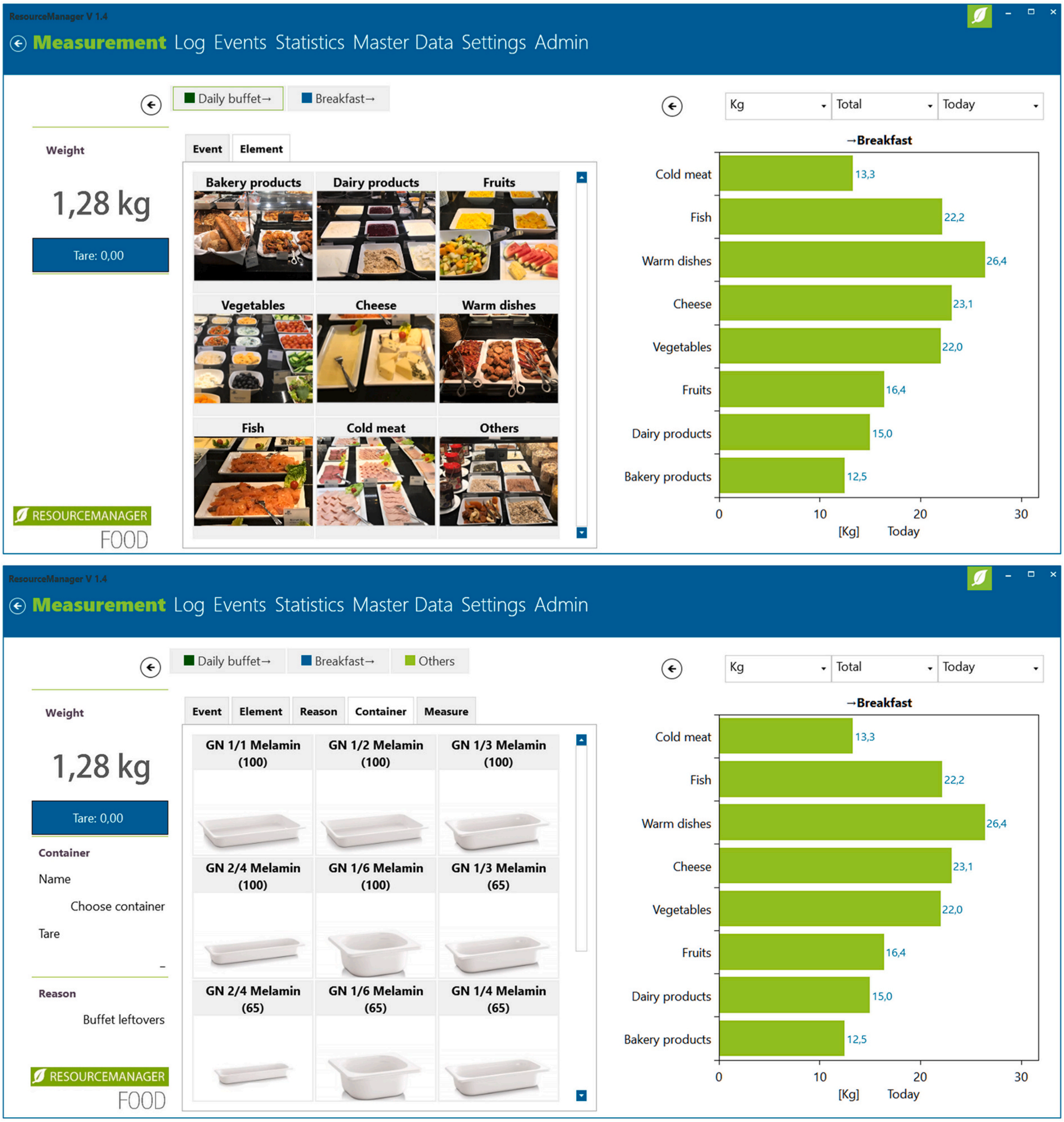

Fig. 1. Screenshots of the user interface of the food waste tracking system called *RESOURCEMANAGER FOOD*.

2.3. Self-reporting effect

For the presentation of results, we compared the monthly mean values of the daily breakfast buffet leftovers with standardized units in mass percentage for each pilot kitchen. To estimate the confidence intervals of the monthly mean values, we used a random resampling procedure with replacement, namely a non-parametric bootstrapping method. The applied bootstrap method is a simple, robust procedure that allowed us to draw statistical inferences without assuming the distribution of the sample (Haukoos & Lewis, 2005). For the resampling procedure, we applied 1000 repetitions to calculate bootstrap estimates (mean values) for each sample unit. For the computation of the resampling procedure we used XLSTAT, which works as add-on software for Microsoft Excel (Addinsoft, 2019). The bootstrap confidence intervals were calculated for each month at a confidence level of 95% based on sample units of 28 daily mean values. To facilitate the visual presentation of trends, we set the mean value of the first measurement month equal to 100% and indexed all further measurement data against this starting point ($w_{i,1} \approx 100\%$). We calculated differences in quantities of breakfast buffet leftovers over time and expressed them relative to the first month (Eq. (1)).

$$c_i = 1 - \frac{w_{i,n}}{w_{i,1}} \tag{1}$$

with

Fig. 2. Sample photos of breakfast buffet leftovers and weighing procedure using the food waste tracking system.

Table 1
Sample characteristics.

	Hotel A	Hotel B	Hotel C	Hotel D
State	Saxony	Schleswig-Holstein	Bavaria	Baden-Wuerttemberg
City	Dresden	Timmendorfer-Strand	Munich	Stuttgart
Number of rooms	328	241	349	555
Guest clientele	Business and tourism	Mainly tourism	Mainly business	Business and tourism
Start of measurement	June 2014	September 2014	December 2015	July 2015

c_i = Differences between the arithmetic mean values of breakfast buffet leftovers from month *n* and the first month in Hotel *i*

$w_{i,1}$ = Arithmetic mean value of breakfast buffet leftovers during the first month in Hotel *i*;

$w_{i,n}$ = Arithemtic mean value of breakfast buffet leftovers during month *n* in Hotel *i*.

For subsequent statistical tests, we followed the current statements of the American Statistical Association, which recommend a simplified dichotomy between significant and non-significant findings concerning misuses of *p* values. Thus, good statistical practices provide a variety of numerical and graphical summaries of data, while a single index should not be a substitute for scientific reasoning (Wasserstein & Lazar, 2016). Accordingly, graphical summaries of data and the use of confidence intervals increase the validity of results instead of using *p*-values for statistical inference (Matthews, 2018). With reference to these recommendations, we strengthened the significance of our statistical tests by calculating bootstrap quotients based on the sample data in all possible combinations (Eq. (2)).

$$c_{ijk} = 1 - \frac{\mu_{ik,n}}{\mu_{ij,1}} | j \cup k = \{1; 2; \ldots; 1000\} \quad (2)$$

with

c_{ijk} = Differences between the bootstrap estimates of breakfast buffet leftovers from month n and the first month in Hotel i;

$\mu_{ij,1}$ = Bootstrap estimates of breakfast buffet leftovers during the first month in Hotel i;

$\mu_{ik,n}$ = Bootstrap estimates of breakfast buffet leftovers during month n in Hotel i.

By forming bootstrap quotients, we obtained 1000,000 observations at a confidence level of 95% and plotted them as relative frequency distributions. The resulting histograms illustrate the distribution limits of the bootstrap quotients at a certainty level of 95% and thus provide information on the strength of the self-reporting effect. According to Cumming and Finch (2005), we used graphical summaries of the results to test Hypotheses H_0 and H_1 based on the principle of inference by eye.

2.4. Monetary savings potential

To investigate the monetary savings potential associated with the intervention of self-reporting, we analyzed the breakfast buffet leftovers at the level of product groups. These product groups represent all food products offered at the breakfast buffet in the pilot kitchens. The outcomes are based on the average across the four hotels for each product group. To visualize the product-specific monetary savings potential, we compared the periods with approximately constant mean values ($\overline{w}_{const}$) with the first measurement month ($\overline{w}_1$) under the simplifying assumption that the first measurement month could be considered the status quo. The cost estimation for each product group is based on the weighted arithmetic average values of all food purchases made by the hotel kitchens, excluding the value-added tax.

2.5. Influence of guest numbers

The pilot kitchens considered the number of guests who had booked breakfast during their stay in the hotel to plan the breakfast buffet and to estimate the food demand. The pilot kitchens, however, did not have access to real-time information about the number of guests who had already visited or were still planning to visit the breakfast. To develop an understanding of how guest numbers influenced the breakfast buffet leftovers within the self-reporting intervention, we applied a bivariate linear regression.

2.6. Reduction measures

To observe the self-reporting effect without additional influences, we did not implement additional interventions that could influence the breakfast buffet leftovers of the pilot kitchens, except for the weighing and self-reporting process. We instructed the kitchen on how to operate the measuring equipment adequately but did not provide further consultancy such as information on how to avoid and reduce buffet leftovers. Consequently, we conducted informal interviews with the managers of the pilot kitchens to collect qualitative information on whether they developed and carried out their own measures or strategies to reduce breakfast buffet leftovers during the self-reporting intervention.

3. Results

3.1. Self-reporting effect

Fig. 3 shows the monthly average of the daily breakfast buffet leftovers. The corresponding bootstrapping intervals and trend lines are displayed over the 12-month investigation period. On average, daily quantities of buffet leftovers ranged between 6.69 kg (Hotel D) and 8.48 kg (Hotel C) during the first month, with a corresponding arithmetic mean for all the hotels of 7.47 kg per day. Compared with the first month, breakfast buffet leftovers decreased steadily over the following five months in all four kitchens. The achieved reductions thereby differed amongst the hotels in their order of magnitude. However, after the fifth month, the buffet leftovers stabilized at an almost constantly low level ($w_{i,\ const}$) in each hotel. Based on this observation, we assumed that the average amount of breakfast buffet leftovers that occurred between month 5 and month 12 can be interpreted as the period that represents the achieved reduction for each pilot kitchen. Consequently, the most striking observation to emerge from the data comparison is the remarkably high degree of reduced breakfast buffet leftovers in each of the hotels. Hotel B achieved the relatively highest savings with a reduction of approximately 84.3%. This resulted in a constant mean value ($w_{B,\ const}$) of 15.7%, relative to the first month ($w_{B,\ 1}$). Hotel A reduced its breakfast buffet leftovers of approximately 76.1% ($w_{A,\ const} \approx 23.9\ \%$), followed by Hotel C with a reduction of approximately 54.0% ($w_{C,\ const} \approx 46.0\%$). Hotel D achieved the lowest relative savings and reduced breakfast buffet leftovers by approximately 42.7% ($w_{D,\ const} \approx 57.3\%$). The results provide a satisfactory impression of the existing potential for savings at the breakfast buffet in the pilot kitchens and illustrate the potential for improvements.

To further test the hypotheses presented at the beginning of the article, we calculated the distribution parameters of the relative reductions with a bootstrapping method, namely a random resampling with replacement. The histograms in Fig. 4 present the relative frequency distribution for the reduced breakfast buffet leftovers and illustrate the strength of the self-reporting effect within the distribution limits at a certainty level of 95%. The histograms show a negative left-skewed distribution in all cases, indicating that days with higher savings were more common than days with lower savings. The effect that breakfast buffet leftovers decreased on a monthly average seems to be strong according to the information presented in the distribution plots. The magnitude of the effect is described within the limits of the

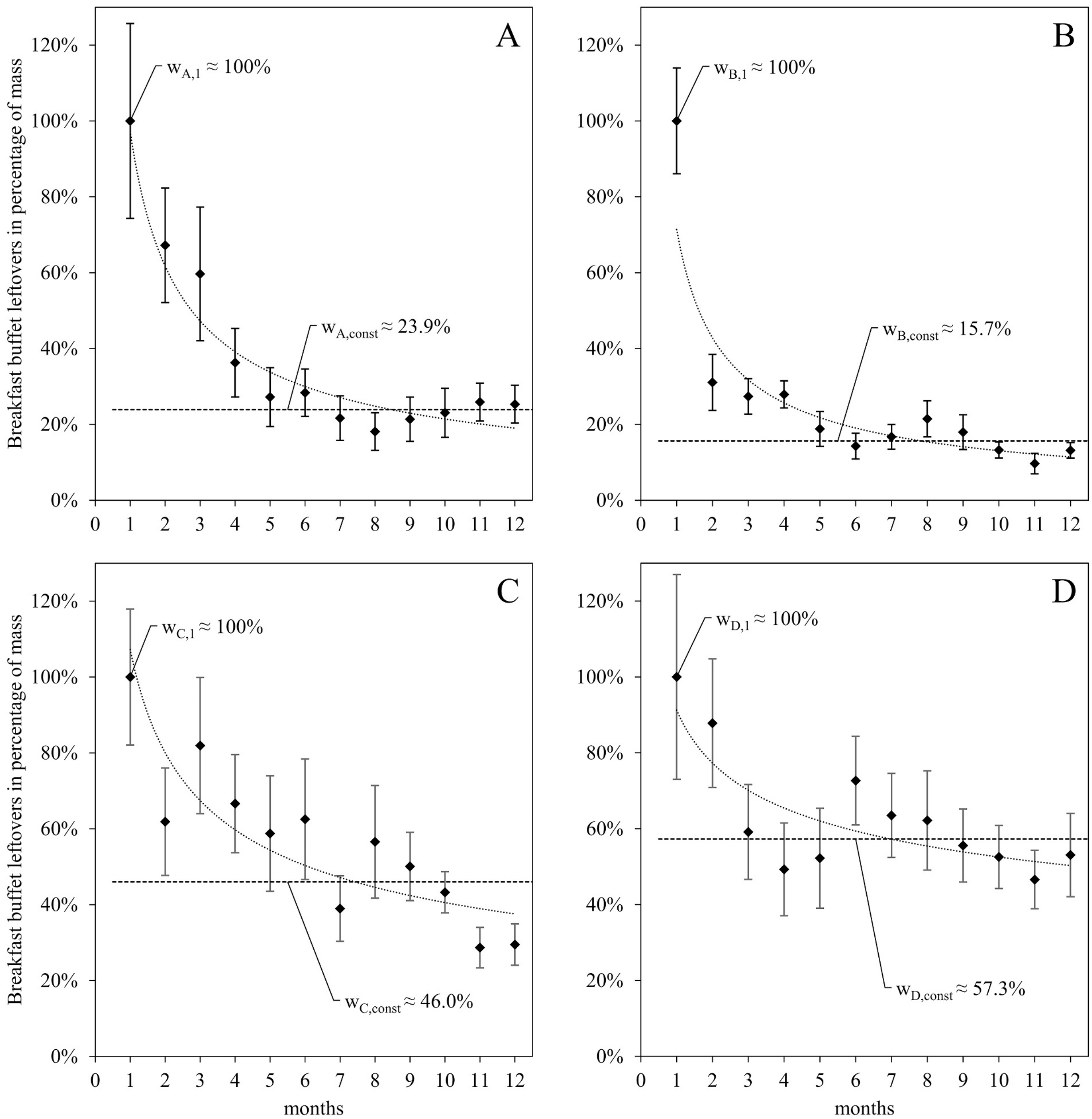

Fig. 3. Breakfast buffet leftovers in four hotels (Monthly mean ± bootstrap confidence interval). The 100% value represents the monthly mean of the daily breakfast buffet leftovers during the first measurement month. A: *Hotel A* (100% = 7.78 kg/d); B: *Hotel B* (100% = 6.94 kg/d); C: *Hotel C* (100% = 8.48 kg/d); D: *Hotel D* (100% = 6.69 kg/d); $w_{i,1}$ represents the arithmetic mean value of the first month; $w_{i,const}$ represent the arithmetic mean value of months 5 to 12.

distribution boundaries indicated on the abscissas of the histograms in Fig. 4. Thus, we observed the strongest effect in Hotel B and could confirm that the expected true value is higher than 0.770 and smaller than 0.887. In other words, the achieved reduction of breakfast buffet leftovers ranges between 77.0% and 88.7% for Hotel B. The distribution for the other hotels is more widely spread, indicating that the reductions were subject to greater fluctuations than in Hotel B, which showed an average reduction of 84.3%. We did not observe the same strength and characteristic of the self-reporting effect in each hotel, but we determined a coherent trend in terms of a reduction over time. On average, buffet leftover in the other pilot kitchens were reduced by 76.1% in Hotel A, 54.0% in Hotel C and 42.7% in Hotel D. The average reduction across all four hotels was thus 64.3%.

Based on these findings, we can show with a certainty of 95% that there is an effect or exclude that the effect is not present. These results further strengthen our confidence that self-reporting effect leads to reductions of breakfast buffet leftovers. Thus, we conclude that we can reject hypothesis H_0 and accept hypothesis H_1.

3.2. Monetary savings

Table 2 lists the breakfast buffet leftovers and their monetary equivalents aggregated at the product group level as an average across all four hotels. The first measurement month ($\overline{w}_1$) is displayed in comparison to the period with an approximately constant mean value ($\overline{w}_{const}$) and the overall savings ($\overline{w}_1 - \overline{w}_{const}$). Even though the indicated prices are dynamic and depend on case-specific conditions, they allow us to get a good insight into the magnitude of possible monetary savings associated with the self-reporting intervention.

The product categories that have a high purchasing price per kilogram are *fish*, *cold meat*, *cheese,* and *others*. However, *bakery products* and *warm dishes* have the highest potential for overall monetary savings,

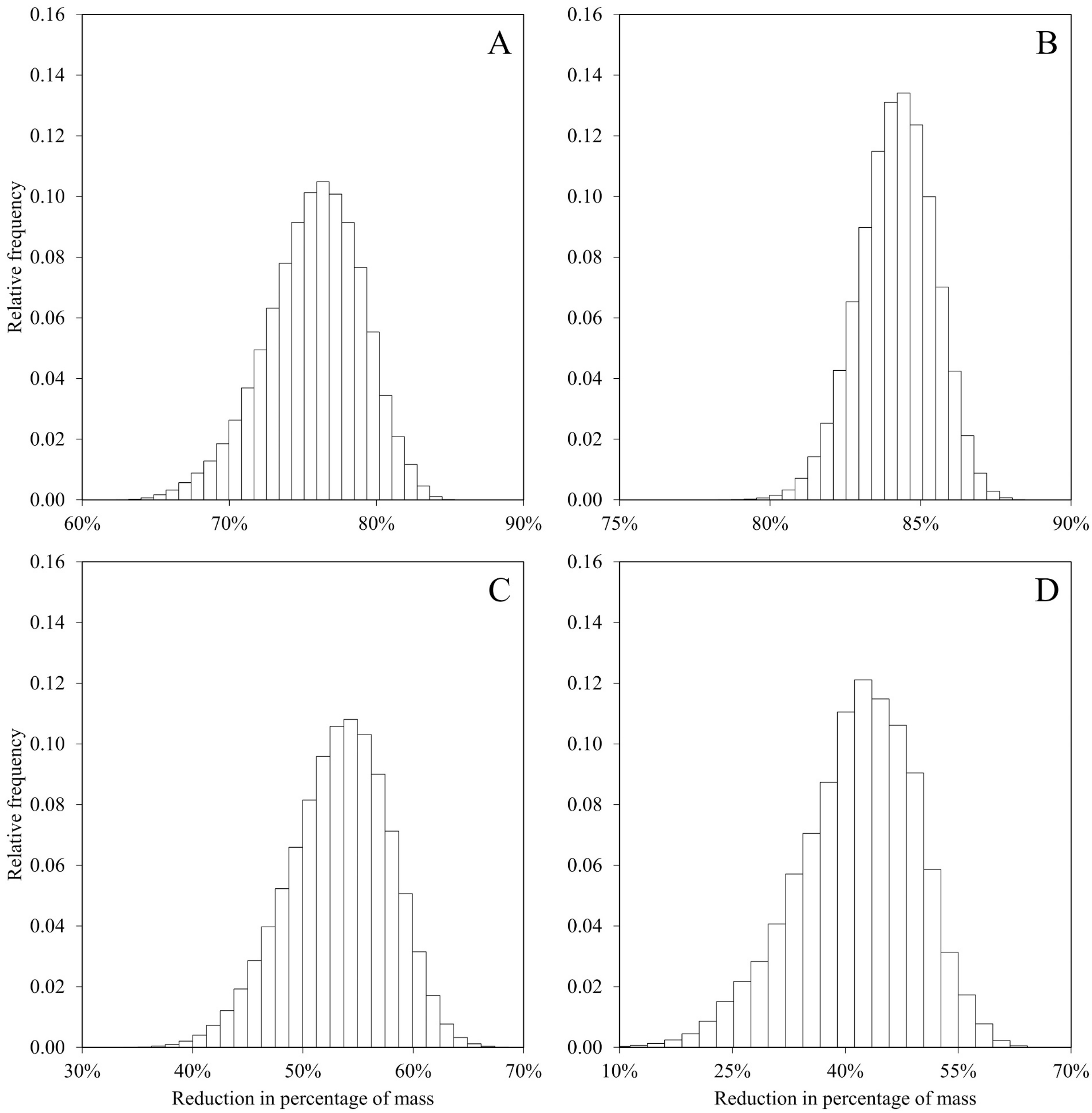

Fig. 4. Relative frequency distribution of the achieved reductions of breakfast buffet leftovers in percentage of mass for A: *Hotel A*; B: *Hotel B*; C: *Hotel C*; D: *Hotel D*.

Table 2
Self-reported quantities and monetary equivalents of breakfast buffet leftovers in four hotels at product group level (average values across all four hotels). The first measurement month ($\overline{w}_1$) is displayed in comparison to the period with an approximately constant mean value during month 5 to month 12 ($\overline{w}_{const}$) and the resulting overall savings ($\overline{w}_1 - \overline{w}_{const}$).

	Breakfast buffet leftovers in kg/d			Price[a] (EUR/kg)	Monetary equivalents in EUR/d		
Category	$\overline{w}_1$	$\overline{w}_{const}$	Savings $\overline{w}_1 - \overline{w}_{const}$		$\overline{w}_1$	$\overline{w}_{const}$	Savings $\overline{w}_1 - \overline{w}_{const}$
Bakery products	2.59	0.87	1.72 (−66.4%)	4.85	12.56	4.22	8.34 (−66.4%)
Warm dishes	2.02	1.05	0.97 (−48.0%)	4.85	9.80	5.09	4.71 (−48.1%)
Fruits	0.80	0.16	0.64 (−80.0%)	3.40	2.72	0.54	2.18 (−80.2%)
Cold meat	0.50	0.21	0.29 (−58.0%)	8.95	4.48	1.88	2.60 (−58.0%)
Dairy products	0.48	0.16	0.32 (−66.7%)	3.72	1.79	0.60	1.19 (−66.5%)
Fish	0.33	0.05	0.28 (−84.9%)	12.26	4.05	0.61	3.44 (−84.9%)
Cheese	0.29	0.05	0.24 (−82.8%)	4.90	1.42	0.25	1.17 (−82.4%)
Others (e.g., jam)	0.29	0.04	0.25 (−86.2%)	5.40	1.57	0.22	1.35 (−86.0%)
Vegetables	0.18	0.08	0.10 (−55.6%)	2.36	0.43	0.19	0.24 (−55.8%)
Total	7.48	2.67	4.81 (−64.3%)		38.82	13.60	25.22 (−65.0%)

[a] Weigthed arithmetic average of all food purchases by the hotel kitchens used for the breakfast, excluding the value-added tax.

Industrial Marketing Management 93 (2021) 617–627

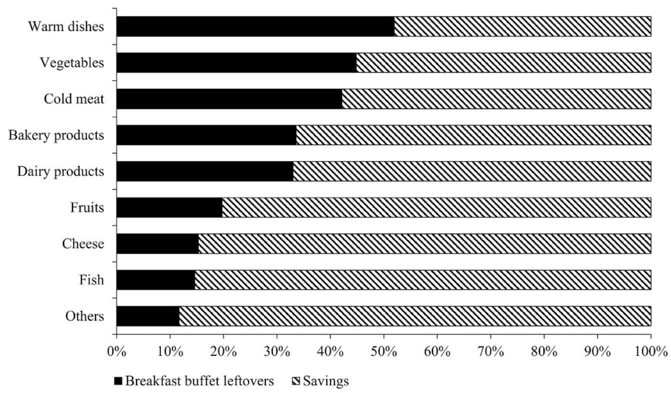

Fig. 5. Monetary savings of breakfast buffet leftovers for each product group based on the average across all four hotels.

which is related to their relatively high amounts of buffet leftovers at the breakfast. Across the four hotels, the total potential for monetary savings during the first month resulted in an average of EUR 38.82 per day. From this amount, an overall saving of approximately EUR 25.22 per day was achieved. The corresponding relative savings for each product group are visualized in Fig. 5 in the order of increasing savings. *Warm dishes, vegetables,* and *cold meat* showed monetary savings between approximately 48% for *warm dishes* and 58% for *cold meat.* Monetary equivalents of wasted bakery and dairy products were reduced by more than 66%. The highest savings were recorded for *fruits*, *cheese*, *fish,* and *others*, each with a decline of more than 80%.

3.3. Influence of guest numbers

Table 3 presents the summary statistics of the linear regression model, which examined the influence of guest numbers on breakfast buffet leftovers for the period before ($w_{i,1}$) and after ($w_{i,const}$) reduction. The coefficients of determination (R^2) demonstrated that guest numbers explained between 0.3% (Hotel A) and 10.8% (Hotel C) of the variance in buffet leftovers before they were reduced and between 1.0% (Hotel A) and 6.2% (Hotel B) after they were reduced. The correlation coefficients showed both negative and positive values, revealing that there were only weak correlations between the number of guests and buffet leftovers. For instance, Hotel C showed a weak positive correlation ($r = 0.329$) before and a weak negative correlation ($r = -0.176$) after buffet leftovers were reduced. The variables did not consistently provide significant information to the model. The regression models thus indicate that guest numbers had a rather weak or no influence on breakfast buffet leftovers.

3.4. Reduction measures

The qualitative interviews with the managers of the pilot kitchens revealed that self-reporting interventions lead to the autonomous implementation of several measures that required simple operational changes during the serving time. One such measure, for example, was the use of smaller units of serving dishes to present the food at the buffet. The use of smaller serving dishes enabled the pilot kitchens to prepare less volumes of food just-in-time to refill the buffet, particularly during the last 30 min of the breakfast time. Even though estimates on the number of guests were used prior to the breakfast time for the menu planning and preparation of food, the pilot kitchens had no real-time information on the number of guests who had already visited or were still planning to visit the breakfast buffet and therefore did not develop reduction measures accordingly. Hence the real-time information about the guest numbers was not a prerequisite for the kitchen to make operational changes and to reduce breakfast buffet leftovers.

4. Discussion

4.1. Self-reporting effect

The main finding of our study is an evident reduction of breakfast buffet leftovers in all pilot kitchens that have implemented a self-reporting intervention. The effect of the self-reporting was of varying intensity within the four pilot kitchens. The hotels reduced between 42.7% (Hotel D) and 84.3% (Hotel B) of their breakfast buffet leftovers. In this context, our study confirms empirical findings in the literature that have demonstrated significant reductions of food waste while using a self-reporting approach in pilot households (Leverenz et al., 2019; Quested & Johnson, 2009). A self-reporting process in general is an aspect of self-awareness and is associated with adaptive reactions that may be expressed by behavioral changes (Zimmerman, 2002). As the hypothesis tests showed, our experimental data demonstrate a strong

Table 3
Summary statistics of the bivariate linear regression. The influence of guest numbers on breakfast buffet leftovers is shown for the period before ($w_{i,1}$) and after ($w_{i,const}$) reduction.

		Before reduction[a] ($w_{i,1}$)			After reduction[b] ($w_{i,const}$)		
	Variable	Non-standardized	Standardized[c]	SE	Non-standardized	Standardized[c]	SE
Hotel A	Intercept	9.072		4.509	2.161*		0.219
	Guest numbers	−0.003	−0.057	0.012	−0.001	−0.100	0.001
	R^2	0.003			0.010		
	F	0.080			2.249		
Hotel B	Intercept	5.291*		1.782	0.517*		0.156
	Guests numbers	0.006	0.187	0.006	0.002*	0.249*	0.001
	R^2	0.035			0.062		
	F	0.947			14.687*		
Hotel C	Intercept	5.804*		1.652	5.565*		0.648
	Guests numbers	0.016	0.329	0.009	−0.004*	−0.176*	0.002
	R^2	0.108			0.031		
	F	3.156			7.041*		
Hotel D	Intercept	7.261*		1.438	3.770*		0.132
	Guests numbers	−0.002	−0.106	0.004	0.001	0.099	0.001
	R^2	0.011			0.010		
	F	0.297			2.214*		

[a] F (DF=1; 26)
[b] F (DF=1; 222)
[c] Standardized coefficients are equal to the linear correlation coefficient (Pearson's r)
[*] $p<0.05$

positive effect caused by the self-reporting, which led to substantial reductions. Thus, the achieved reductions are related to the individually developed reduction measures of each pilot kitchen. Practical and organizational changes included improvements such as the use of smaller serving dishes for the food presentation and refilling the buffet with less quantities during the just-in-time production. However, the self-reporting effect may incorporate other influences that we did not control such as the social desirability aspect or bias (Althubaiti, 2016). This is in line with observations in the literature on the complexity of singling out the effects of one specific measure (Stöckli et al., 2018).

4.2. Monetary savings potential

The monetary savings for each kitchen resulted in an average of approximately EUR 25.22 per day. Under the simplifying assumption that the self-reporting effect will remain present, and that the four hotels will continue to save these amounts of waste without additional measurement costs, each kitchen could save approximately EUR 9000 per year. These findings are consistent with non-scientific case studies and success stories. For instance, Clowes et al. (2018) presented data from 86 catering operations that reduced on average 44% of food waste quantities and 56% of the monetary equivalents during a period of three years. However, the monetary savings in our study are based on hotel-specific purchase prices. The working hours for the preparation of the meals and the disposal costs are not included in this estimation. The food waste tracking system was provided to the hotel at no cost, whereas in general, the cost for introducing and leasing such a system would also obtain a better estimate of the associated monetary savings potential of self-reporting. Considering these factors, the effective monetary savings would probably result in slightly different values.

On average, the pilot kitchens achieved significant monetary savings of breakfast buffet leftovers in all product groups. Product categories with the highest quantitative savings were not always associated with the highest monetary savings because of their comparatively low product price. Scherhaufer et al. (2018) found a similar pattern for food products with regard to their ecological footprint. Meat products, for example, generally have a higher ecological footprint than vegetable products, but often show an inverse pattern for the amount of waste. Therefore, a thorough sustainability assessment would be required to determine the effectiveness of the reduction measures with regard to their economic and environmental impact (Goossens et al., 2019).

4.3. Influence of guest numbers

The linear regression models revealed that the variable of guest numbers did not provide sufficient information to explain the generation or reductions of breakfast buffet leftovers. The correlation coefficients ranged from negative to positive values between the pilot kitchens, which indicates that correlations may either depend on the individual food management of each kitchen or that there was no correlation at all between the number of guests and breakfast buffet leftovers. The goodness of fit was relatively low, which means that there could be a non-linear correlation between these two variables. However, although the number of guests did not show significant influences on the breakfast buffet leftovers in our case study, this might not be the case for other types of buffets or food services. For instance, the number of guests showed a strong influence on the generation of buffet leftovers at catered events such as conferences, graduation ceremonies or business events (Leverenz et al., 2020). According to other literature, the precise knowledge of the number of guests enables some kitchens to forecast the food demand and thus to control the amount of food waste (Pirani & Arafat, 2016). As such, although the kitchen administration considered the guest numbers prior to the breakfast for menu planning and the preparation of food, the guest numbers showed only a rather weak influence on how much food returned from the buffet to the kitchen. However, a thorough analysis of how the number of guests influence menu planning, overproduction and buffet leftovers was out of the scope of this paper, which emphasizes the need for further research.

4.4. Reduction measures

As several studies have shown, there are many drivers for the generation of food waste and possibilities to reduce it (Betz et al., 2015; Giorgi, 2013; Göbel, 2018; Marthinsen et al., 2012). Heikkilä et al. (2016) showed that it is crucial to attempt to reduce food waste in all aspects, meaning that reduction measures should also be adopted to the concept or philosophy of the business. The results of our case study extend the findings from the literature that have focused on measures to reduce food waste by introducing a self-reporting approach. The effect of the self-reporting intervention apparently resulted in changes of operational routines. The food waste tracking system provided information in real-time, which allowed the implementation of measures within short periods. Improvements were mainly related to the refilling behavior during the last 30 min of the breakfast buffet service and the use of smaller serving dishes for product presentation. The transferability of these positive effects to other kitchens requires the identification of individual reduction potentials (Eriksson et al., 2017). For this purpose, the self-reporting approach was not only suitable for measuring the waste but also provided the necessary information for the development and implementation of individual reduction measures.

Technical assistance to measure food waste exists in the form of different types of digital scales and food waste tracking systems. Some of them are commercially available from several providers, as described in the introduction section. Based on the positive effects of the self-reporting intervention, we conclude that food waste tracking systems deliver relevant information that may result in significant food waste reductions and monetary savings. Eriksson et al. (2019) found that catering units that use tracking systems instead of semi-automated or manual tools record more data and achieve slightly higher reductions in food waste. Hence, systematic monitoring and reporting are essential to evaluate interventions and measures. Other software solutions, such as *Delicious Data*, provide forecast solutions using machine learning to combine historical data from gastronomic kitchens with external factors to predict the future demand for the preparation of meals. These forecasts offer information for kitchen management in terms of procurement, menu planning and daily production (Delicious Data GmbH, 2019). Despite using tracking systems and forecasting tools, gastronomic kitchens might sell their leftovers to environmentally conscious consumers at a discount by using smartphone applications such as *ResQ* or *To Good To Go* (ResQ Club, 2019; Too Good To Go, 2019). Another alternative is cooperating with charity organizations such as those who have food distribution initiatives (FEBA, 2019; Foodsharing, 2019).

4.5. Critical remarks and data quality

The findings of our paper have some limitations, which we briefly discuss in this section. As part of our empirical investigation, we analyzed the effect of self-reporting by using the example of breakfast buffet leftovers, which resulted in a restriction of the observational framework. Thus, we were unable to provide a comprehensive overview of the overall savings potential of food waste in these hotels, which could theoretically have been achieved in reducing plate leftovers and wasted food during storage and preparation. In our study, the kitchen staff performed the measurements and operated the food waste tracking system. The quality of the collected data during the self-reporting approach might therefore be influenced by errors during the practical conduction of the measurement. Based on Berthelot et al. (2011), our experimental conditions may have influenced the reported data even before the measurements started because the participants were aware of their involvement in this study. Another possibility is that the pilot kitchens may have consciously reported less waste than was actually produced to improve their self-reporting performance. With this experimental setup, we could not calculate a systematic error in the results. However, this is not in conflict with the main findings of our study because regardless of whether the participants were under-reporting or not, they consistently showed the same positive pattern regarding the reduction of buffet leftovers.

4.6. Further research

The results of our case study have shown that self-reporting interventions can be very effective to improve operational kitchen routines and reduce buffet leftovers. Although we demonstrated that optimization at the breakfast buffet can be conducted successfully, the transferability to other forms of catering and buffets must be examined. This examination should include lunch and dinner buffets, and the *à la carte* service in hotel restaurants or other types of food services such as the catering of business canteens, school canteens, individual events, or fast food services. In further investigations, it might also be possible to investigate the effectiveness of different prevention strategies and reduction measures. For instance, information on the monetary efficiency of reduction measures could provide important incentives for businesses in the food service sector to develop prevention strategies. However, the possibility of being able to reduce food waste through the application of self-reporting interventions serves as an incentive for further research to build up on the positive findings of our case study and to investigate its potential for different types of buffets and food services.

4.7. Final considerations

The European Union is committed to fulfill Sustainable Development Goal 12.3 of the United Nations, which aims to halve food waste at the consumer level by 2030 (European Commission, 2018). Our study provides information on the feasibility of achieving food waste reductions in the hospitality sector by focusing particularly on buffet leftovers. On average, breakfast buffet leftovers were more than halved and would thus even exceed the political reduction targets. However, it is still necessary to identify to what extent these promising results can be scaled up to other meals throughout the day, to other serving styles (such as *à la carte*), and to a larger number of businesses in the food service sector. We encourage policy makers at regional and national levels to promote the practical implementation of these types of measures. Such initiatives can provide a substantial contribution to achieving parts of the target set by the United Nations.

5. Conclusions

Food waste tracking demonstrated a clear improvement in the food management of the pilot kitchens. Breakfast buffet leftovers decreased at the beginning of the investigation and stabilized at a constantly low level after approximately five months. The findings of our study demonstrated that self-reporting interventions can reduce breakfast buffet leftovers in hotels by more than half. The achieved reductions were related to prevention strategies that each pilot kitchen individually developed according to their self-reported data. Simple operational changes such as the use of smaller serving dishes and refilling the breakfast buffet with less quantities of food that was prepared just-in-time seemed to be very effective improvements. The practical viability of reducing buffet leftovers serves as an incentive for further research to improve the methodological approach of our study and validate the concept by, for example, testing whether self-reporting interventions also contribute to reducing food waste for other types of buffets and food services.

Declaration of Competing Interest

We have no conflicts of interest to disclose.

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