Full length article

Quantifying the prevention potential of avoidable food waste in households using a self-reporting approach

Dominik Leverenz[a],[*], Salua Moussawel[a], Claudia Maurer[a], Gerold Hafner[a], Felicitas Schneider[b], Thomas Schmidt[b], Martin Kranert[a]

[a] *Institute for Sanitary Engineering, Water Quality and Solid Waste Management, University of Stuttgart, Bandtäle 2, 70569 Stuttgart, Germany*
[b] *Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries, Bundesallee 63, 38116 Braunschweig, Germany*

A B S T R A C T

The prevention of avoidable food waste at consumer level is an issue of increasing importance, yet persists with no evident solution. Recently the Sustainable Development Goals of the United Nations (SDG) set a new challenge to overcome in sustainable consumption, namely the target 12.3 to halve food waste by 2030 at retail and consumer level. This paper aims to show that it is indeed possible for households to achieve this target using an approach that builds on positive effects of interventions and kitchen diaries. We present an intervention method that is not only beneficial to gather data regarding avoidable food waste in households, but also contributes to reduce it. In this context, we compared the short-term impacts of two different types of self-reporting and coaching methods to reduce avoidable food waste in households. Therefore we implemented in two separate panels of households in the same area once an offline-system and once a web-based online-system. The study outcomes are based on experimental data collected in these two sets of household panels demonstrating a clear improvement in the participant's behavior regarding food purchase and waste production. The main finding of our study is a reduction of avoidable food waste by more than 50% of fresh mass for both panels, showing that households can achieve this part of the SDG 12.3. Based on the method's effectiveness, we encourage its wider use and further development.

1. Introduction

Over the years, food waste has become a pressing issue with annually more than 88 million tons of wasted food in Europe and more than 1.3 billion tons worldwide (Gustavsson et al., 2011; Stenmarck et al., 2016). This correlates with a global loss of about 24% of total freshwater resources used for food crop production, 23% of the total cropland area and 23% of total fertilizer use (Kummu et al., 2012). The avoidable food waste, generated by consumers in Europe, results in a blue water footprint of around 27 liters per capita and day, which corresponds in its magnitude with the total municipal blue water consumption in Europe (Vanham et al., 2015). On the other hand, the global demand for food will rise by up to 60% per capita in the year 2050 according to forecasts of the Food and Agriculture Organisation of the United Nations (Alexandratos and Bruinsma, 2012). The target 12.3, under the Sustainable Development Goals (SDG) set by the United Nations (UN), aims to halving food waste at retail and consumer levels by 2030 and reducing food losses along

production and supply chains, including post-harvest losses (United Nations, 2015). Thus, it has become a high priority to reduce food waste, especially in industrialized countries due to a relatively high amount of consumer food waste. In order to resolve this issue on a household level, research brought about many studies generating knowledge on the optimal ways to quantify and analyze collected data (Ogwueleka, 2013; Jörissen et al., 2015; Hanssen et al., 2016; Schneider, 2016; Delley and Brunner, 2017; Hübsch and Adlwarth, 2017; Corrado and Sala, 2018; Delley and Brunner, 2018; Elimelech et al., 2018). Some solution-seeking studies use interventional methods to encourage consumers to reduce their avoidable food waste (Smith et al., 2014; Young et al., 2017; Shaw et al., 2018). Successful approaches would contribute to "nudge" consumers resulting in a food waste prevention without having them to change their attitudes or increasing their efforts drastically (Hebrok and Boks, 2017). Research in the field of behavioral and social science offers important insights on how to nudge people into better decision-making (Thaler and Sunstein, 2009). Amongst other findings, it became apparent that people

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feel uncomfortable when their behavioral reflection lead to the conclusion that they waste more food than others (Parizeau et al., 2015). The understanding and promoting of pro-environmental behavior can contribute significantly to long-term environmental sustainability, it is therefore important to facilitate a sustainable behavior for individuals (Steg and Vlek, 2009). Another motivator to reduce food waste for consumers, besides the environmental benefit, is the intention to not waste money (Baker et al., 2009; Graham-Rowe et al., 2014). However, triggering consumers by external interventions based on provision of information about environmental impacts and financial benefits often result in no positive outcome (Smith et al., 2014; Shaw et al., 2018). Consequently, Shaw et al. (2018) recommends actions that are centered on the awareness of the householder's food use and the wasted food type in relation to the product and its life cycle stage (Shaw et al., 2018). In the community-based approach "Love Food Hate Waste", households received awareness raising sessions on how to better manage their food. The initiators, the Waste and Resources Action Programme (WRAP), collaborated with the National Federation of Women's Institutes (NFWI) and arranged personal gatherings for the participants of the study to share their experiences and learn food waste prevention tips from designated representatives. Even though the results were based predominantly on qualitative collected data, they showed highly positive outcomes, noting considerably that the communal nature of the project led to its success. A notable factor mentioned, was that the participants felt empowered to take the lead on resolving the issue on self-developing their food waste knowledge and skills (Falcon et al., 2008). A proposed approach that provides essential information on the disposal behavior of consumers with regard to the prevention of food waste is the use of kitchen diaries (Richter and Bokelmann, 2017; Young et al., 2017). Richter and Bokelmann (2017) found that the use of kitchen diaries is suitable to get insights to the handling with food in households and showed the existing linkage between food storage, purchase and waste. However, a large number of existing literature generated substantial knowledge regarding the household behavior, analyzing drivers to reduce food waste (Hebrok and Boks, 2017). The realization of a successful concept requires the understanding that awareness is not a one-dimensional concept, but rather a mix of analogue and digital measures allowing the most promising impact when implemented (Gelbmann and Zimek, 2018).

Based on the above-mentioned studies, we used the self-reporting method to analyze the short-term effects within an interventional approach using kitchen diaries accompanied by additional coaching and awareness raising measures. Similar studies also provide the success of this method in a household context (Richter and Bokelmann, 2017; Young et al., 2017). Therefore, the main objective of our paper is to present a possible solution method which contributes to prevent avoidable food waste in households. We introduce the positive impacts of an interventional investigation that ran for three 1-month periods in the District of Ludwigsburg, Germany. We will present the observed short-term effects of using a kitchen diary in which we show trends and possible solutions on how to prevent food waste at the consumer level and discuss the findings while considering the UN Sustainable Development Goals Target 12.3 of halving food waste at household level.

2. Material and methods

2.1. Definitional framework

The definitional framework in our study is consistent to Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste, which defines food waste as all food[1] that has become waste. As we focus exclusively on the avoidable part of food waste from households, we refer in our definition of avoidable food waste to existing publications (Quested and Johnson, 2009; Katajajuuri et al., 2014; Hanssen et al., 2016; Visschers et al., 2016). In line with these investigations, avoidable food waste includes all edible parts of the food, which the consumer normally intends to eat when purchasing the food.

2.2. Study area

The participating pilot households are located in the administrative district of Ludwigsburg, Baden-Württemberg, Germany. In 2011, about 510,491 inhabitants lived in the district of Ludwigsburg in about 228,768 households (Statistik-BW, 2018a, 2018b). The average household size of 2.2 persons corresponds to the regional average of the federal state of Baden-Württemberg. In Ludwigsburg, about 136 kg/(cap·year) of residual municipal solid waste is collected via the municipal solid waste collection system, while another 42 kg/(cap·year) of organic household waste is collected separately as well as recyclables. These values are within a similar range compared to the nationwide average (DESTATIS, 2013). We therefore assume that the participating pilot households generate an average amount of avoidable food waste corresponding to the national average between 33.4 and 43.3 kg per capita and year, or between 91.5 g/(cap·d) and 118.6 g/(cap·year) respectively (Hafner et al., 2012).

2.3. Experimental design

Within this explorative study, we compared the short-term impacts of two different types of coaching methods to reduce avoidable food waste in households. We conducted two panel studies in the district of Ludwigsburg, both using a method of self-reporting. The first panel (Panel 1) worked with an offline self-reporting system, based on netbooks with an installed spreadsheet software. In addition, we provided paper forms to households that preferred working without the netbooks. We carried out personal communication through face-to-face dialogues within the coaching sessions. The second panel (Panel 2) used a web-based online platform to document and report its data. We used this online platform to communicate and display information within the coaching sessions to the participants without any additional personal meetings. Both panels started the self-reporting process in the first month without receiving any awareness-raising information, thus allowing us to get an insight into their behavior prior to the coaching sessions. In contrast to similar interventional approaches using kitchen diaries (Young et al., 2017), we worked with the terminus *coaching* and not with the terminus *intervention* to describe the disseminated awareness information to the participants, since diary keeping is an intervention itself and is therefore associated with changes in the reported quantities (Delley and Brunner, 2018).

2.4. Sample characteristics

In order to recruit households, we called for participation using various media platforms, such as message boards, leaflets and regional newspapers. The households differ in the number of adults and children, as well as in their age and household income. Table 1 provides the main characteristics of the sample, the methodical approach and the time horizon. Panel 1 documented their consumer behavior between March and May 2011 while Panel 2 participated between March and May 2012. The investigation phase lasted in both panels over a period of three months, divided into equal sections of 28 days, named accordingly period 1, period 2 and period 3 (see Table 1). In general, the panel does not represent the average German household.

2.5. Procedure and coaching

The procedure of the intervention contains three periods of self-reporting including a four-week coaching block with particularly

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[1] Food is defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council.

Table 1
Sample characteristics.

Sample characteristics		Quantity of households	
State District	Baden-Württemberg Ludwigsburg	Panel 1 (n = 16)	Panel 2 (n = 37)
Household size	single-person household two-person household three-person household four-person household five-person household	1 6 6 3 0	11 10 2 10 4
Children	one child two children more than two children	4 6 0	3 11 4
Methods	Self- reporting Coaching	Offline-based Face-to-face interaction	Online-based Online interaction
Time horizon	Period 1 (28 days) Period 2 (28 days) Period 3 (28 days)	03/07/11 - 04/03/11 04/04/11 - 05/01/11 05/02/11 - 05/29/11	03/05/12 - 04/01/12 04/02/12 - 04/29/12 04/30/12 - 05/27/12

compact information for both panels (see Fig. 1). In the introductory phase (Period 1), prior to the start of the investigation, participants received basic instructions regarding the procedure of the self-reporting process and the documentation of data by using kitchen diaries. Considering that the panels did not yet receive any coaching, the collected data were taken as initial values, hence useful for determining the status quo.

In the second period (Period 2), both panels received three consecutively coaching sessions with intensified awareness raising information. We disseminated information with participating households from Panel 1 within personal meetings through direct communication accompanied by additional information in printed forms (e.g. flyers, instructional guides, etc.) and objects for demonstration purposes (e.g. fresh and expired food). The online communication with Panel 2 was strongly oriented towards a practical implementation possibility with the intention to reduce efforts of the coaching sessions in terms of personnel and financial resources. The information stream via the internet represents a compromise between the availability of a larger circle of participants and simultaneous depth of information. Content of the coaching sessions included for both panels awareness raising information, which is comparable to similar studies (Smith et al., 2014;

Young et al., 2017; Falcon et al., 2008; Shaw et al., 2018). In the first coaching session, participants received a graphical evaluation of their individual results during the self-reporting in the first month. This type of intervention method aimed to enable a self-reflection of the individual purchasing and disposal behavior with the intention to increase sensitivity towards a more conscious decision-making process when buying and discarding food. The participants of both panels were also required to document their main disposal reasons to enable the derivation of related conclusions by the participants themselves when reflecting their individual disposal behavior. The subsequent coaching session in week 6 contained specific information regarding smart shopping (e.g. using shopping lists), shelf life of perishable and packaged food, adequate storage and handling for different food types, better meal planning and recipes on how to create dishes with food that would have been thrown away otherwise (e.g. old bread to dumplings, cooked potatoes to fries, etc.). To intensify the awareness regarding shelf life of food, participants distinguished on a voluntary base between a fresh and expired yoghurt by visual, olfactory and sensorial tests. The concluding coaching session in week 8 provided further incentives such as a feedback of the so far reduced food waste in form of a benchmarking with other pilot households. In addition, we encouraged
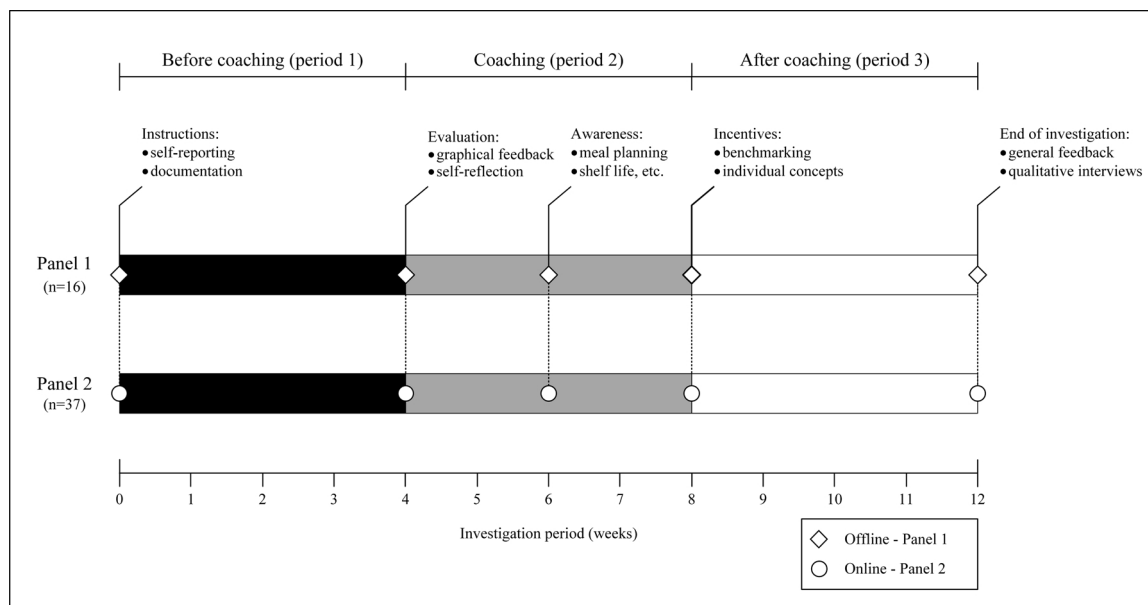

Fig. 1. Timeline of the self-reporting intervention and its related coaching content.

households to develop their own ideas and strategies regarding food waste prevention and to implement them on a trial basis in their daily life.

In the third period, households received no additional coaching sessions while maintaining the same kind of self-reporting to collect data and monitor progress, therefore we mark period 3 as the "after coaching" phase. This period presents a short-term observation of the influence of the coaching sessions on the participants' purchasing and disposal behavior. At the end of the investigation, participants gave a general feedback within qualitative interviews regarding the self-reporting process, related problems and benefits (see Fig. 1).

2.6. Study approach

Participants of both panels documented and reported their food management in specifically designed kitchen diaries. Panel 1 worked with offline-based kitchen diaries while Panel 2 used an online-based kitchen diary. In order to determine the status quo, the participants recorded every wasted food item by mass and day. The pilot households used a conventional kitchen balance to measure the mass of the avoidable food waste and food purchases by mass and day. The weighing process of the purchased food items within Panel 1 was associated with a disproportionately high temporal expenditure in relation to the effort for the measurement process and the correlated findings regarding the reduction of avoidable food waste. Based on these empirical learnings, we reduced the effort for the proceedings in Panel 2 by asking participants to report their avoidable food waste by weighing, but to report their food purchases in form of summarized monetary values from the purchasing receipts. This should reduce the temporal expenditure and efforts during the reporting period and strengthen the data quality regarding avoidable food waste. For the further evaluation and comparison of purchased food, we transformed the gravimetric values from Panel 1 into monetary values based on harmonized indices of consumer prices from Hafner et al. (2012). Beverages like water, juices, milk and alcoholic drinks were not measured.

2.7. Data analysis and presentation of results

We evaluated the reported data by comparing mean values (M) of the food waste quantities in households for both panels. To describe the dispersion of the sample, we calculated the standard error (SE) for each mean value. We analyzed the avoidable food waste of the pilot households and distinguished the examined data into the categories *bakery products*, *meat and fish*, *vegetables*, *dairy products*, *fruits*, *pasta products*, *leftovers* and *others*. The results are presented within vertical bar graphs with the standardized units in mass percentage for avoidable food waste and monetary percentage for purchased food. The corresponding inhabitant specific mass and monetary specifications are also displayed. The graphical presentation of results in mass percent shows the relevance in the context of the 50% prevention target of the United Nations and provides the achieved reductions within the pilot households. In addition, economic aspects of avoiding food waste are derived from the above mentioned mass data.

Analyzing sample data, the Kolmogorov-Smirnov test showed for both panels normal distribution ($\alpha = 0.05$), so that subsequent statistical analyses are subject to parametric tests. We analyzed differences in food purchases and food waste generation before and after the coaching period, using repeated measures analyses of variance (ANOVA). It indicates the impact of the coaching on the consumer's behavior during the self-reporting periods, showing trends and short-term effects.

3. Results

3.1. Prevention of food waste through behavioral change – quantities of purchased and wasted food and correlation to monetary aspects

The outcomes are derived from three separate periods of the interventional approach and two separate panels. A major finding of our investigation is that the implemented methods resulted in a significant reduction of avoidable food waste by more than 50 percent of mass. The pilot households documented an average amount of 49.08 g/(cap·d) in Panel 1 and 34.93 g/(cap·d) in Panel 2 during the initial period prior to the coaching sessions. These self-reported quantities of avoidable food waste are significantly lower as the national German average of at least 91.5 g per capita and day (compare (Hafner et al., 2012)). The graph presented in Fig. 2 shows trends and relations between improvement in food purchase and waste production during the period of investigation. Panel 1 lowered its overall expenditures on food about 15.7% after the coaching period, while Panel 2 spent 25.7% less on food purchases. The food waste trends show a steadily, almost linear decline before, during and after the coaching, both for offline (Panel 1) and online (Panel 2)

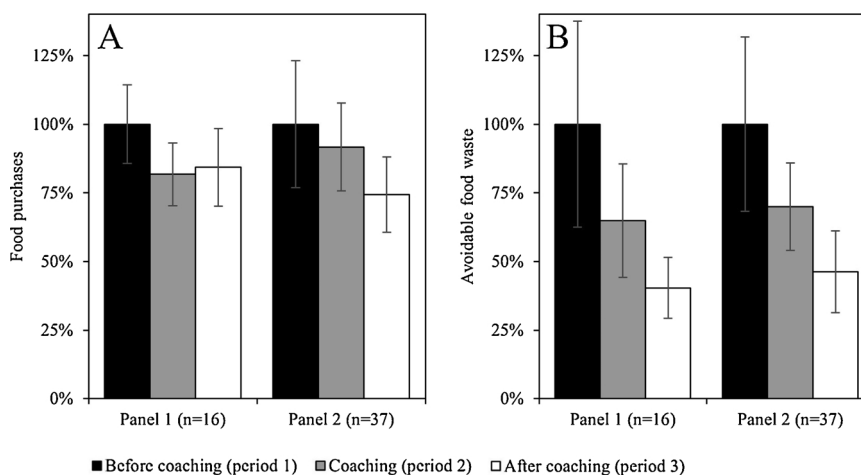**Fig. 2.** Trends in amounts of purchased food (**A**) and avoidable food waste (**B**) in total (M ± SE). **A**: Panel 1 (100% = 5.60 EUR/(cap·d)); Panel 2 (100% = 3.86 EUR/(cap·d)). **B**: Panel 1 (100% = 49.08 g/(cap·d)); Panel 2 (100% = 34.93 g/(cap·d)).

Table 2

Mean values (M) and standard error (SE) of avoidable food waste before and after coaching.

Avoidable food waste	Panel 1 (n = 16)				Panel 2 (n = 37)			
	M[1]	SE[1]	M[2]	SE[2]	M[1]	SE[1]	M[2]	SE[2]
Before coaching (period 1)	49.08*	18.39	0.21*	0.07	34.93*	11.09	0.15*	0.05
After coaching (period 3)	19.81*	5.45	0.10*	0.03	16.16*	5.22	0.06*	0.02
Changes of mean values (M)	−29.27		−0.11		−18.77		−0.09	
	(-59.6%)		(-52.4%)		(-53.7%)		(-60.0%)	

* Differences of mean values are significant (ANOVA, p < 0.05).
[1] g/(cap·d).
[2] EUR/(cap·d): Data transformed with values from table 69 in Hafner et al. (2012), p.119.

Table 3

Monetary Mean values (M) and standard error (SE) of purchased food.

Food purchases	Panel 1 (n = 16)[1]		Panel 2 (n = 37)	
	M[2]	SE[2]	M[2]	SE[2]
Before coaching (period 1)	5.60*	0.80	3.86*	0.89
After coaching (period 3)	4.72*	0.79	2.87*	0.53
Change of mean values (M)	−0.88		−0.99	
	(-15.7%)		(-25.7%)	

* Differences of mean values are significant (ANOVA, p < 0.05).
[1] Data transformed with values from table 69 in Hafner et al. (2012), p. 119.
[2] EUR/(cap·d).

interaction (compare Fig. 2, B). Comparatively, we also observe an overall reduction of food purchases after the coaching sessions compared to the status quo, but no consistent reduction trend for Panel 1 (compare Fig. 2, A).

Table 2 presents the mean values (M) and standard error (SE) of avoidable food waste before and after the coaching and shows the resulting changes of mean values. Panel 1 reduced its average avoidable food waste by more than 59.6% of mass during the three months of investigation from 49.08 g/(cap·d) to 19.81 g/(cap·d) within the offline-based approach. A similar improvement of waste reduction occurred within the online-based self-reporting, decreasing avoidable food waste by more than 53.7% of mass from 34.93 g/(cap·d) to 16.16 g/(cap·d). The achieved reduction of food waste correlates with a monetary value in the range of 0.09 and 0.11 EUR per capita and day. According to this, the pilot households could theoretically save between 32.85 and 40.15 EUR per capita and year through the improvement of their food waste management (see Table 2).

Table 3 presents the monetary mean values and standard errors of purchased food for both panels. Comparing the collected data shown in Tables 2 and 3 of purchased and wasted food, we observed that all mean values in the offline-based approach are higher than in the online approach (compare Tables 2 and 3). Concerning the expenses of food, our findings also demonstrate a change in the consumer behavior of the pilot households. After coaching, the participants of Panel 1 spent on average 0.88 EUR/(cap·d) less on grocery shopping than before. Panel 2 showed a similar trend, spending 0.99 EUR/(cap·d) less on food than before (see Table 3). According to this, the participants in our study could theoretically save between 321.2 EUR/(cap·year) and 361.4 EUR/(cap·year) by a more conscious purchasing behavior, including overall optimized food management.

The repeated measures analyses of variance (ANOVA) assert that

Table 4

Mean values (M), standard error (SE) and percentage distribution of avoidable food waste at product group level.

Avoidable food waste		Panel 1 (n = 16)				Panel 2 (n = 37)			
		M	±	SE	M[1]	M	±	SE	M[1]
Before coaching (period 1)	Bakery products	5.57	±	2.61	11.4	4.75	±	1.76	13.6
	Meat and fish	1.97	±	1.83	4.0	1.42	±	1.41	4.1
	Vegetables	10.75	±	6.72	21.9	9.03	±	4.35	25.8
	Dairy products	5.23	±	2.28	10.7	4.34	±	2.25	12.4
	Fruits	12.39	±	10.32	25.2	7.55	±	5.85	21.6
	Others	2.67	±	2.69	5.4	2.55	±	1.42	7.3
	Pasta products	4.32	±	2.73	8.8	0.73	±	0.48	2.1
	Leftovers	6.17	±	2.83	12.6	4.57	±	2.68	13.1
	Total amount	49.08	±	18.39	100.0	34.93	±	11.09	100.0
Coaching (period 2)	Bakery products	6.65	±	2.95	20.9	2.97	±	1.24	13.9
	Meat and fish	2.75	±	1.85	8.6	1.25	±	0.83	5.8
	Vegetables	11.29	±	8.08	35.5	4.77	±	2.08	22.2
	Dairy products	2.36	±	1.48	7.4	3.22	±	1.48	15.0
	Fruits	3.64	±	1.58	11.4	4.09	±	1.67	19.1
	Others	0.44	±	0.49	1.4	1.89	±	1.22	8.8
	Pasta products	0.67	±	0.50	2.1	0.35	±	0.32	1.6
	Leftovers	4.03	±	2.09	12.7	2.92	±	2.17	13.6
	Total amount	31.84	±	10.15	100.0	21.46	±	5.56	100.0
After coaching (period 3)	Bakery products	3.16	±	1.45	15.9	2.55	±	1.25	15.8
	Meat and fish	3.66	±	2.53	18.5	0.50	±	0.26	3.1
	Vegetables	5.53	±	2.77	27.9	5.61	±	3.68	34.7
	Dairy products	1.23	±	1.08	5.8	1.39	±	0.66	8.6
	Fruits	2.70	±	1.99	13.6	3.22	±	1.57	19.9
	Others	0.33	±	0.29	1.7	0.93	±	0.61	5.7
	Pasta products	0.75	±	0.74	3.8	0.52	±	0.61	3.2
	Leftovers	2.54	±	2.11	12.8	1.44	±	1.01	8.9
	Total amount	19.81	±	5.45	100.0	16.16	±	5.22	100.0

[1] percentage distribution of avoidable food waste.

differences of the mean values for purchased and wasted food are not random. The test results are statistically significant at a significance level of 5%, which introduces behavioral changes regarding the shopping and disposal behavior. In addition, data is distinctly wider scattered for food waste than for food purchases, which illustrates related uncertainties by encouraging consumers to change their disposal behavior in terms of food waste prevention (compare Fig. 2). Furthermore, we observe for the wasted food that the distribution (bandwidth) of the sample values decreases, indicating an increase in conscious behavior of disposing food (compare Fig. 2B). Additionally, we found the confidence interval (M ± SE) reduced in total and closer to the mean in the third period. In general, the results show a consistent positive pattern in both panels asserting the two aforementioned targeted behavioral changes of purchasing and wasting food.

3.2. Food waste trends related to product groups

Table 4 presents detailed information on the avoidable food waste generation at product group level and also provides data about the waste composition for all periods. Initial data from period 1 show that vegetables, fruits, bakery products and leftovers dominate the average composition of the discarded food. These product groups caused in total more than 71.1% (Panel 1) and 74.1% (Panel 2) of the wasted food during period 1 prior to the coaching sessions. Therefore, these four products represent the predominant groups of avoidable food waste within our panels. Furthermore, the results in Table 4 demonstrate that participants of both panels reduced their avoidable food waste at product group level for all products except for the group *meat and fish*, where a contradictory effect is seen in Panel 1, increasing in average from 1.97 g/(cap·d) up to 3.66 g/(cap·d).
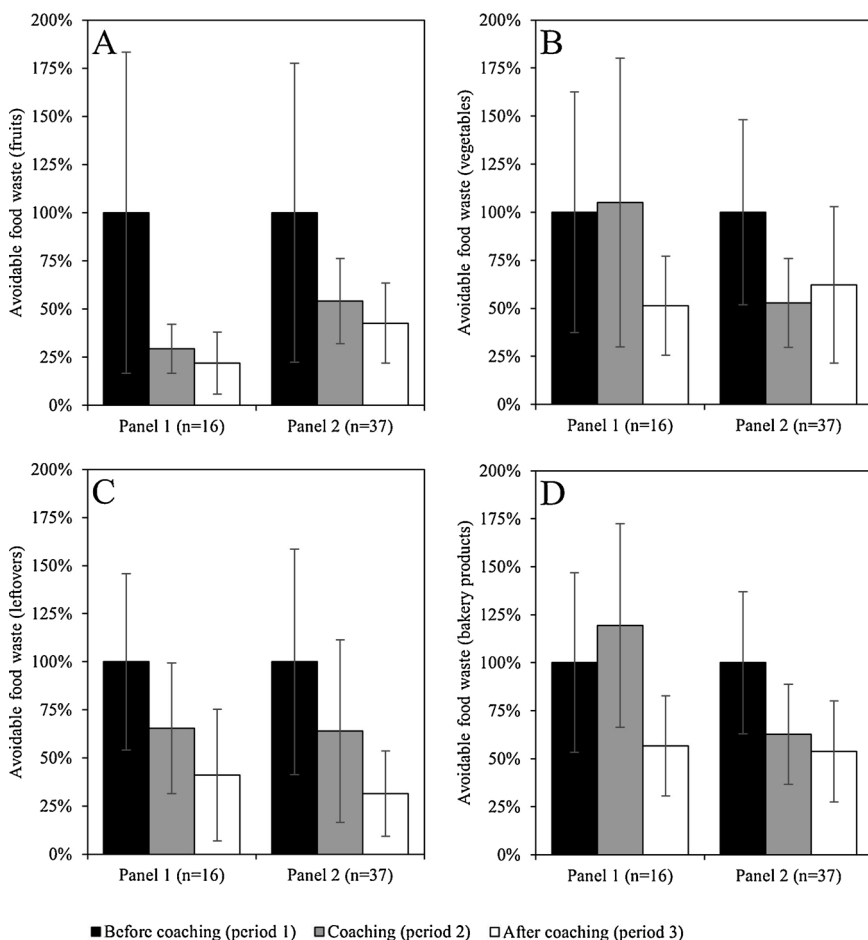
Fig. 3 illustrates data from Table 4 for the aforementioned four predominant product groups and shows the respective trends in amounts of avoidable food waste. We observe a steady decline for fruits and leftovers in both panels during the whole period of investigation resulting in a reduction of more than 50% of mass. While vegetables showed in both panels to be one of the highest quantified food waste types within the first month, we found that the time for which each group of participants reduced their avoidable food waste differs in the two panels. Panel 1 reduced its vegetable food waste after the second month, while Panel 2 had a quicker response towards the coaching showing a reduction after the first month, noting however no further improvement in the third month. Bakery products decreased between 43.3% (Panel 1) and 46.3% (Panel 2) of mass, while Panel 1 generated more food waste during the coaching (period 2) compared to the status quo before the coaching (compare Fig. 3).

3.3. Trends in relation to household size

Fig. 4 shows trends in amounts of avoidable food waste in the two panels during the three-month study. We observed that all participants living in households of different sizes reduced their avoidable food waste significantly. In both panels we noticed a steady decrease in the waste quantities, while the four person households in Panel 2 were an exception, as the amount of avoidable food waste during coaching first increased slightly and then decreased. During the offline-based approach in Panel 1, all households reduced their avoidable food waste by at least 50% of mass. Two person households achieved the highest prevention with a 69% reduction of mass, while single and three person households halved their food waste resulting in a similar congruent decline. Within the online-based approach (Panel 2) single and two
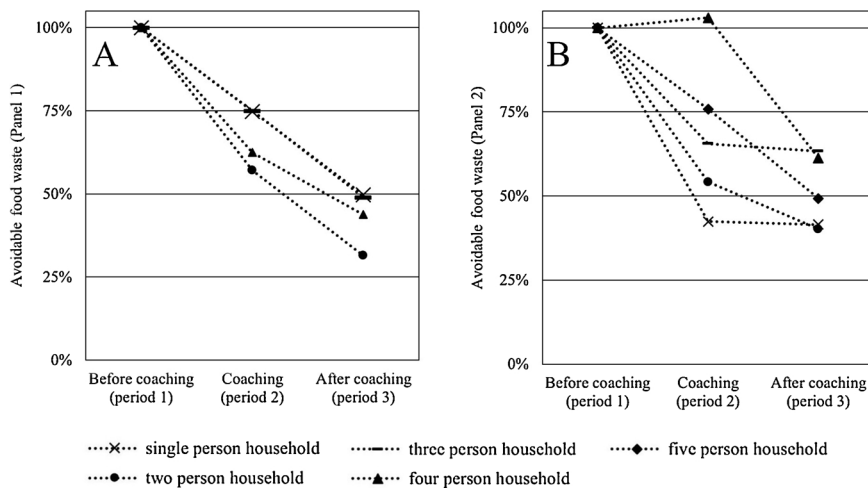

Fig. 3. Trends in amounts of avoidable food waste (M ± SE) for the predominant product groups: fruits (**A**), vegetables (**B**), leftovers (**C**) and bakery products (**D**). **A**: Panel 1 (100% = 12.39 g/(cap·d)); Panel 2 (100% = 7.55 g/(cap·d)). **B**: Panel 1 (100% = 10.75 g/(cap·d)); Panel 2 (100% = 9.03 g/(cap·d)); **C**: Panel 1 (100% = 6.17 g/(cap·d)); Panel 2 (100% = 4.57 g/(cap·d)); **D**: Panel 1 (100% = 5.57 g/(cap·d)); Panel 2 (100% = 4.75 g/(cap·d)).

■ Before coaching (period 1)   ▨ Coaching (period 2)   □ After coaching (period 3)

Fig. 4. Trends in amounts of avoidable food waste (M) for Panel 1 (**A**) and Panel 2 (**B**). **A:** Single person household (100% = 2.25 g/(cap·d)); Two person household (100% = 21.65 g/(cap·d));. Three person household (100% = 16.67 g/(cap·d)); Four person household (100% = 8.52 g/(cap·d)). **B:** Single person household (100% = 13.05 g/(cap·d)); Two person household (100% = 9.55 g/(cap·d)); Three person household (100% = 1.81 g/(cap·d)); Four person household (100% = 5.83 g/(cap·d)); Five person household (100% = 4.70 g/(cap·d)).

person households achieved a reduction of their avoidable food waste by more than 50% of mass, while five person households halved their amount. Four person households reduced their avoidable food waste by 39% of mass and three person households by 37% of mass, achieving relatively lower reductions compared to other household sizes within the panel (see Fig. 4).

3.4. Reasons for food wastage

We collected qualitative information regarding disposal reasons for both panels. Participants documented the reasons associated to their disposal behavior as an indicator for possible behavioral changes. In general, the most frequently mentioned reasons for food wastage within our panel were attributed to *cooking too much, spoiling during storage, not using saved leftovers in time, expired shelf life, mistakes in handling and other reasons* like not having sufficient space in the refrigerator or no more interest in eating a specific food again. The significant decline of avoidable food waste in the participating households is influenced by these mentioned reasons and is related to behavioral changes like better meal planning, adequate storage, higher awareness in using leftovers in time, purchasing planning, preparing the meal and increased awareness on the value of food.

4. Discussion

4.1. Quantitative and qualitative findings concerning food waste and food purchases

The results of our study provide detailed insights regarding trends and possibility to reduce avoidable food waste in the context of the UN target (SDG 12.3) to halve food waste at the consumer level. The diary method in general is suitable to obtain detailed data regarding consumer behavior and to capture additional information on waste disposal that is not collected by local authorities (Richter and Bokelmann, 2017). The main finding of our research demonstrates an evident food waste reduction in both panels by more than 50% of mass, which would meet the target of halving food waste at household level. Consequently, participants benefited from a direct monetary saving due to changes in their shopping behavior and from an indirect monetary saving due to the prevention of food waste, resulting from food preparation and waste fees. Thus, the presumable reduction of food costs can be an additional driver to motivate people to continue improving their purchasing habits, especially because it is directly related to how well participants engage in food waste reduction practices. This relation of food purchase and wastage was also shown by an explorative study about the analysis of storing, purchasing and wasting food by using household diaries (Richter and Bokelmann, 2017). Participants also changed their

purchasing behavior within our study, resulting in a decrease of purchased food between 15.7% (Panel 1) and 25.7% (Panel 2) after the coaching sessions compared to the initial state. Unlike the food waste trends, food purchases did not decrease linearly, showing a slight increase within households of Panel 1 after the coaching. The observed difference between both panels of their reduced purchasing quantities and related trends are probably caused by the sample characteristics. The larger overall sample size of Panel 2 with a considerably higher number of four and five person households lead to a higher reduction of purchases, but to a lower reduction of food waste compared to Panel 1. On one hand, these differences could be caused by a higher flexibility in the purchasing behavior of four and five person households due to a larger number of options when buying food with smaller or bigger packaging sizes. On the other hand, a higher number of people living in the household increases the complexity of reducing the food waste due to a related higher inhomogeneity of eating habits within the household. However, the relatively small sample size of both panels did not allow a reliable derivation of a function between household size, purchasing and disposal behavior.

Participating households already actively separated their residual wastes, organic wastes and recyclables within the established separate collection of municipal household waste. We presume according to existing findings that environmentally conscious households generate less food waste (Williams et al., 2012). However, the study showed no association or increased likelihood of participants' interest or initiative to minimize or prevent food waste. The group of people within our panel had to self willingly agree to be part of the project, narrowing the group to mainly interested individuals with distinctive intentions and qualities. We did however benefit from the diversity of the household inhabitants' family characteristics, revealing that all types of households with different sizes achieved a significant reduction of food waste. The majority of the panels' households achieved a reduction of more than a half of their food waste with exception of the three person households (-37% of mass) and four person households (-39% of mass) of Panel 2. We did not observe a relation between household size and food waste amounts, as it was found in other studies (Parizeau et al., 2015; Hanssen et al., 2016). The positive response of the participants for all household sizes demonstrates the possibility to encourage households towards a behavioral change and the prevention of avoidable food waste. The first panel however, contained only one single membered household, weakening our generalization that a single person reduces food waste after coaching. In the second panel, we obtained more conclusive results due to the presence of eleven single-person households. The achieved reduction of (non-preserved) perishables in the food waste, such as fruits and vegetables, and food with a short shelf life, such as bakery and dairy products, indicates better storage and planning habits of the pilot households. Leftovers comprise

an evident decreasing trend, which implicates behavioral change in daily habits that may have been affected by the consumers' perception on food and portion size (meal planning). The other food waste types' quantified decline lead to the conclusion of smarter food purchasing habits in relation to portion calculation and management. Consistent to similar studies, the results on food waste composition are predominated by vegetables, fruits, bakery products and leftovers (Smith et al., 2014; Hanssen et al., 2016; Hübsch and Adlwarth, 2017; Shaw et al., 2018). This means that possible recommendations for action to reduce food waste in households should focus in particular on these categories in terms of quantitative avoidance strategies. On the other hand, wasted product groups such as meat, fish or dairy products cause a comparatively higher environmental impact than vegetable and other products such as fruit and bakery products (Vanham et al., 2015). In order to strengthen the effectiveness of a comprehensive avoidance strategy, each measure should consider aspects like its environmental footprint.

The complexity within studies analyzing household behavior including the identification of reasons relating to their disposal behavior was already shown by several studies (Williams et al., 2012; Visschers et al., 2016; Delley and Brunner, 2017; Russell et al., 2017). The reasons considered in our study were grouped into five categories in order to be able to classify associated changes in behavior. We found improvement amongst others in meal planning, food storage and portion sizing due to behavioral changes. These observations support the conclusions regarding food waste trends in our study, but do not allow detailed derivations of recommendations for starting points based on the reasons given.

When tested statistically, we found significant differences between mean values after the coaching. This relates both to food purchases and to food waste and implies a success of the methodical approach, while the standard error is relatively higher for food waste trends compared to food purchasing trends. In overall, we observed a statistically confirmed improvement of shopping and disposal habits.

4.2. Limitations of this study

The main limitations of our study are inaccuracies due to influences, which likely occur during self-reporting research. Participants may willingly or unwillingly forget to record items, choose not to record them and change recording in favor of less waste generation. This may lead to underreporting of food waste quantities by the participants and does not allow the determination of any systematic error in the results (Quested and Johnson, 2009). Another study confirms this observation resulting in a tenfold discrepancy comparing data from self-reported quantities with extrapolations from waste compositional analysis (Delley and Brunner, 2017). However, the diary method is suitable to quantify reliable data on food waste in households working with a representative and trained consumer panel as a recent study from Germany shows (Hübsch and Adlwarth, 2017). The results of our study do also express underreporting as compared to the German average (Göbel et al., 2012; Hafner et al., 2012; Hübsch and Adlwarth, 2017), yet this does not conflict with the observed overall decline of participants' food waste and purchase. Whether the participants were underreporting or not, they consistently did so, considering that our interventions did not include any warnings to prevent this issue. However, the qualitative results of the offline and online approach deliver similar outcomes, which are comparable with results from other studies (Smith et al., 2014; Hanssen et al., 2016; Hübsch and Adlwarth, 2017; Shaw et al., 2018). Further, weaknesses arise in the sustainability of the observed reductions due to the fact that the timeline of this investigation was limited to the period of three months. Considering the group of participants themselves in terms of diversity of characteristics and number of pilot households, our panel is not representative for the general population. However, the outcome of our research delivers a high content of information for each sample due to the relatively long and consistent measurement period of three months, which is more

extensive than in similar research (Richter and Bokelmann, 2017; Young et al., 2017).

4.3. Considerations and recommendations

The results of our study give a good impression on how the numbers of food waste reduced rapidly, considering that pilot households achieved the SDG target of halving food waste on a regional level in such a short term. Young et al. (2017) also observed a food waste reduction during a self-reporting analysis, even for the control group, which did not receive any intervention (Young et al., 2017). In contrast, other literature (Smith et al., 2014; Shaw et al., 2018) shows that external interventions does not lead to food waste reductions, when self-reporting and a communicative exchange with the panel does not take place. For this reason, we consider the self-reporting effect in combination with the coaching sessions as an important factor within our study in achieving a significant reduction of food waste. Due to the sample size of the panels, the findings of our study do not claim compliance with the statistical requirements regarding the representativeness of results. Thus, transferring and upscaling these findings to other households in a wider framework, related problems and prospects of success still need to be examined in future research projects. Empirical observations during the implementation of the study showed that the self-reporting procedure, in particular the weighing and documentation process, required a considerable amount of time for the participating households. In addition, the accompanying awareness-raising activities also involved a considerable organizational, personnel and financial expenditure regarding the scientific project management. For this reason, the online-based approach of Panel 2 achieved a practical feasibility allowing the integration of a larger number of participants while simultaneously reducing personnel and financial expenditures for the coaching sessions. In order to determine a sustainable acceptance of the self-reporting approach and related documentation methods, we propose a subsequent investigation in pilot scale before transferring this approach into practice. This essentially includes the conduction of the self-reporting approach within the framework of a statistically representative sample size in order to provide evidence regarding the required upscaling capacities. In this context, we propose the cooperation with organizations that could contribute to the dissemination of information in order to overcome difficulties in reaching a larger number of households. These include public institutions such as schools and administrations, non-governmental organizations or charities. Furthermore, the implementation of the self-reporting method in gastronomic kitchens of the food service sector obtains an even higher specific potential than its use in households. This is due to the fact that the number of portions cooked in a gastronomic kitchen is several times higher than in household kitchens, in which related efforts to reduce food waste are relatively lower with simultaneously higher monetary incentives. In total, our study reveals that the use of kitchen diaries is able to contribute significantly to the reduction of food waste.

5. Conclusions

The study outcomes of both sets of household interventions demonstrate a clear improvement in the participants' behavior regarding food purchase and food waste prevention. We are convinced that self-reporting can be a useful precondition to initiate a change in consumer behavior, even if it cannot be separated from the influence of the intervention itself. Providing additional awareness raising information in order to support households and to initiate a self-reflection of individual purchasing and disposal behavior enable a further reduction of food waste. The implemented measures within our study were not associated with any restrictions in the everyday eating habits of households like constraining their out-of-home eating. The purpose was to offer new information for the participants and confront them with their situation and habits. The measures aimed to support the process of

awareness raising actions for households and encourage individual initiatives of the participants on how to reduce their food waste. We also found that the conducted interventions lead to a significant decrease of food waste with the help of food waste diaries in all participating households regardless of their size. The further development of this approach should focus on how to motivate a larger number of households to report or monitor their disposal behavior, respectively to identify instruments and channels to reach and involve them. The cooperation with organizations such as public institutions, non-governmental organizations or charities could give the necessary support to address the target group (consumers) within a wider range. We are convinced that a comprehensive strategy including a self-reporting approach combined with awareness raising actions can lead to significant reduction of avoidable food waste in households.

Declaration of Competing Interest

We have no conflicts of interest to disclose.

Acknowledgements

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