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Food waste reduction and its environmental consequences: a quasi-experimental study in a campus canteen

Seyedeh Fatemeh Fatemi¹, Hassan Eini-Zinab², Fatemeh Manafi Anari², Mahdieh Amirolad², Zahra Babaei² and Seyyed Reza Sobhani^{1*}

Abstract

Background Food waste is the third-largest contributor to greenhouse gas emissions, which has severe environmental and economic effects. This study presents a two-level intervention to estimate the quantity and environmental consequences of food waste at a campus canteen, offering innovative solutions to reduce food waste and its environmental footprint.

Methodology This study involved 300 students and consisted of three main stages: initial food waste assessment, environmental and economic impact evaluation, and qualitative exploration of the causes of food waste through interviews with students. The assessment included direct measures and weighing of leftover food, and the environmental and economic impact was calculated. A two-level intervention was implemented for students and staff, and a re-assessment of food waste was conducted to evaluate the intervention's impact. Statistical analysis was performed using SPSS.

Results The study monitored 26 meals, finding that the total amount of food waste in the university canteens was (mean = 60.65 g/person), and the intervention reduced food waste by 16.35% per meal (50.73 g/person). Moreover, after the intervention, the amount of food waste costs and total water waste were reduced by 30.14% and 16.66%, respectively. Grey water was reduced significantly by 12.5% ($p=0.033$). Interviews with students identified low-quality meals, unpleasant taste, large portions, and a limited menu as the main causes of food waste.

Conclusions It is possible to tackle food waste effectively with educational intervention, decreasing portion size, and improving the quality and variety of food.

Keywords Food waste, Campus canteen, Environmental effects, Iran, Nutritional behavior

Introduction

Climate change requires a global approach that prioritizes sustainability [1]. Coordinated initiatives to address climate change can also improve food security, land management, and nutrition, and help end hunger, while it is estimated that about 30–50% of all food produced is wasted within the food supply chain [2, 3]. Reducing food loss and waste would lower greenhouse gas emissions and promote a sustainable diet [4]. Furthermore, reducing food losses at the earlier stages of the food supply

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chain, such as production, processing, and distribution, can enhance food security and reduce the strain on natural resources, such as land, water, and energy [5]. By reducing the waste in the food supply chain, there would be enough food for about one billion people, which would increase food security and resource efficiency [6]. However, reducing food waste is not sufficient to achieve sustainability; it is also necessary to find innovative solutions to utilize the wasted food and convert it into valuable products and services [7]. Another way to tackle this problem is a sharing economy, which is a way of sharing goods and services without owning them. A sharing economy can help reduce food waste by connecting food producers, retailers, and consumers, and by redistributing surplus food [8].

Food waste exacerbates several public health and environmental issues, including food security, water shortages, and greenhouse gas emissions [9]. Agriculture consumes about 70% of the freshwater supply, and more than 25% of the total freshwater use is wasted due to food waste [10]. A previous study estimated that 1533.5 tons of CO₂ were emitted from farm to table for 1,990 food items, equivalent to the greenhouse gas emissions of 278.82 passenger vehicles in a year [11]. Considering the finite land and water resources, climate change, and the environmental impacts of food production and consumption [2, 3], it is clear that food waste is a global public health and environmental issue that requires the joint efforts of governments, industry, and individuals [12, 13]. One of the ways to address this issue is to apply food waste valorization methods, which aim to recover and utilize the valuable components of food waste, such as nutrients, bioactive compounds, and energy [14].

The main cause of food waste in underdeveloped countries is at the production stage, while in developed countries, it is at the retail and consumption stages [15]. The literature suggests that the main causes of food waste at the consumer level are consumer attitudes, low awareness of food waste and its environmental consequences, lack of planned shopping, and failure to follow a specific diet [16, 17].

However, this can be significantly prevented by actions taken by governments, industry, and people. Implementing clear legislative frameworks, establishing economic instruments such as landfill tax, incineration tax, and “Pay-as-you-throw” schemes, and launching awareness campaigns can reduce the amount of wasted food by 61% and 45% [18]. Moreover, promoting sustainable energy policies in developing countries can also help reduce food waste and improve food security [19].

Measuring the amount of food waste enables us to understand which food items are being wasted and what behaviors cause it. It also allows us to estimate the

cost and value of the wasted food [20]. Educating individuals and raising their awareness are key factors in reducing food waste [21]. Additionally, factors such as environmentally friendly behavior, economic awareness, domestic skills, and collaborative behaviors may make sharing practices more effective in reducing food waste [22]. Some studies have implemented educational interventions, such as holding nutrition classes in schools to raise students’ knowledge about the nutritional benefits of school lunches, as well as the social, economic, and nutritional consequences of wasting food and its negative impacts [21]. Some other examples of interventions include storing food for consuming at another time, promoting consumption, increasing the support from canteen staff, serving smaller meals [23], and reducing dining frequency [11].

Some studies conducted in university canteens have shown how avoidable waste can be reduced by simply raising students’ awareness of the topic of food waste. These strategies can be useful to improve behaviors and increase the sustainability of university canteens [24]. Moreover, another study indicated that the most important factors affecting university students’ food waste generation are multidimensional, such as individual-level and family-level characteristics, catering features, and regional locations [25]. According to these studies, universities have the potential to influence food consumption habits while sustainably managing existing resources. As a controlled environment, the university canteen provides an ideal behavioral laboratory for studying the consumption link in the food system. Students represent the younger generation of consumers; hence, influencing their food-related habits can enhance the sustainability of future food consumption patterns [26–28].

The aim of the present study was (1) to estimate the quantity and the environmental consequences of food waste at the canteen, (2) to study students’ opinions on the causes of food waste through semi-structured face-to-face interviews, and (3) to implement a two-level intervention for students and staff to reduce the food waste.

Method and material

Case study description

This study involved 300 students (all students entering the canteen) from Shahid Beheshti University of Medical Sciences in Tehran (Iran), from November 2018 to January 2019. The faculty had an independent and separate campus from the main campus of the university. The restaurant served approximately 300 meals every day. The inclusion criteria were students who had lunch in the canteen, and who received and ate their food in the canteen after booking their meal in advance. The

present study consisted of three different steps. During the first step, which lasted for 13 days, the leftover food from lunch at the school's canteen was weighed every day after lunch. Since the canteen menu was designed for a 13-day period and then repeated, 13 days were chosen as the number of days for measuring food waste. The assessment of food waste was based on direct measures conducted in the kitchens and at schools by the staff. The staff separated the wasted food from other non-food waste. The foodservice staff received briefings on the quantification procedures before the study period, and they were given paper handbooks with detailed instructions. To avoid bias linked to potential changes in students' food consumption during the data collection period, the foodservice staff knew the real reasons for the experiment.

Food waste assessment

The food waste was measured by direct weighing and sampling, which is one of the most common and accurate methods of measuring food waste. The food waste was divided into two categories: Wasted food consisted of the leftovers from the students' meals and did not include waste generated during food preparation and/or distribution. The data collection process involved weighing the following components: (i) Plate waste, which was the food that the diners discarded after they received their servings and left on their plates; (ii) Intact food, which included the non-served food (i.e., excess servings not served to the canteen) and other food items completely rejected by the canteen (i.e., portions of bread and fruit not collected by the students from the serving trays). The school food service offered three main courses for lunch: the first course was primarily based on a carbohydrate-rich component (such as rice, pasta, or bread), the second course was primarily based on a protein-rich component (such as meat, fish, or eggs) with a side dish of vegetables, and the third course was a portion of bread and fruit. The quantities of prepared food, plate waste and intact food were weighed separately for each lunch meal using an electronic scale (SECA® model WT50001NF, Canada) with accuracy to the nearest gram. The data gathered referred to all the students dining at each school. This quantification allowed us to calculate, for each meal course: (a) Served food (SF), determined by the difference between prepared food (PF) and intact food (IF): $SF = PF - IF$; (b) Non-consumed food (NCF), which was the sum of plate waste (PW) and intact food (IF): $NCF = PW + IF$ (i.e., the portion of prepared food that diners did not consume during lunch); (c) Consumed food (CF), calculated as the difference between the quantity of food prepared for lunch (PF) and the non-consumed food fraction (NCF): $CF = PF - NCF$. The weights

of the students' food waste were measured, and a one-kilogram sample was taken from the total waste daily. This sample was then analyzed for four separate components (total, rice, meat, bread, vegetables, legumes, potato). Subsequently, the components of the sample were separated and weighed using a digital scale with accuracy to the nearest gram (SECA® model WT50001NF, Canada). Then, the average food waste per student was calculated by dividing the total food waste by the number of students eating on that day.

Assessing the environmental and economic impact

The amount of carbon dioxide emitted from the farm to the table to produce that quantity of waste, as well as the amount of green water, blue water, and grey water and total water were all calculated for wasted food.

The 'carbon footprint' method was applied to calculate the amount of carbon dioxide emitted during the food production process. "The term carbon footprint is defined as a measure of the total amount of carbon dioxide emission, both direct and indirect, released by an activity or accumulated over the life stages of a specific product" [29]. Our data regarding the carbon dioxide emissions of each food item were source from the "BCFN DOUBLE PYRAMID DATABASE" and Food Climate List from Swedish University of Agricultural Sciences [30].

We used the water footprint method to measure the amount of water used in the production process of food items. The definition of water footprint is "the total volume of freshwater used to produce the goods and services consumed by an individual or community". The unit for presenting of footprint data for each food item is usually water volume, measured in cubic meter per ton (m^3/ton). The water footprint data were available for Iran [31, 32]. The water footprint comprises three different components: blue, green, and grey, respectively. The blue water footprint is defined as the consumption of blue water resources (which consist of surface and ground water) during the production of a product and throughout its supply chain. The word 'consumption' in this context refers to the utilization of water from available ground-surface water sources within a catchment area. Losses occur in cases such as water evaporation, were being returned to another catchment area or the sea, or the water being turned into a product [33]. The term green water footprint is used to denote the consumption of green water resources, which refers to rainwater that does not become run-off. And finally, the term grey water footprint to pollution and is defined as the volume of freshwater required to absorb the load of pollutants, considering natural background concentrations and existing ambient water quality standards [33]. In

the present research, we calculated water footprint data in term of water volume per gram (m^3/gm). The amount of water required in the process of producing each food item was determined by multiplying the water footprint by the mean food waste of the sample [34]. For example: Water used for wasted rice = Water footprint of rice (m^3/gm) * Average wasted rice (gm).

Also, the cost and calories of the amount of wasted food were calculated. We calculated the cost by multiplying the amount of food waste in grams by the price per gram of each item obtained from the Central Bank of Iran. To evaluate and calculate the nutrient and energy intakes, the software NUTRITIONIST-IV (version 7.0; Squared Computing, Salem, OR, USA) was used.

Regarding the fact that the students are present at the campus for 9 months a year, all the consequences were calculated for 9 months a year instead of 12 months.

Qualitative study

In the second phase, semi-structured face-to-face interviews were conducted with 21 students to explore the causes of food waste at the canteen. It had a flexible structure and a question guide (open-ended questions). The question guide was developed based on the literature review and the research objectives and was pre-tested and revised before the data collection. The interviews were conducted by two trained researchers, which were conducted in a quiet and comfortable room in the school and lasted for about 30 min each. The interviews were recorded with the consent of the participants, and transcribed verbatim for data analysis. Such interviews are well suited for the exploring the perceptions and opinions of respondents regarding complex and sometimes sensitive issues, allowing for probing more information and clarification of answers. Data collection ceased when data saturation occurred.

Interventions for reducing food waste

The third stage consists of two parts: intervention and re-measurement of food waste, each lasting 13 days, which is the same duration as the first stage of our study, where measured the baseline level of food waste. Based on the result of the qualitative study conducted in the second phase, which investigated the causes of food waste through semi-structured interviews, a two-level intervention was carried out for students and staff to increase their knowledge and change their attitudes towards food waste. For the students, a campaign was launched with the motto "This is enough for me". Students in the campaign were informed about the results of the initial 13-day study, which included data on food waste, environmental impact, and estimated cost. To inform the students, pamphlets and posters were used. The results

of the study were posted on the faculty's main electronic board and published on the Telegram[®] channel and the Instagram page of the campus (www.instagram.com/nnftri). Posters with the campaign motto were also displayed on the walls of the campus canteen. Additionally, a brief explanation of motto, encouraging individuals to take only what they needed, was placed next to the canteen buffet. Students were also informed that they could request smaller portions from the staff. To intervene at the staff level, intervention involved training them to serve smaller portions to those who requested less food. In addition, they were instructed to provide bread in smaller pieces, allowing people to take bread according to their needs and avoid excessive portions.

Food waste re-assessment

For the re-measurement of food waste, another 13-day sampling session was conducted. The second sampling session followed the same methodology as the first one, which means that we used the same tools, procedures, and criteria to collect and analyze the food waste data. For example, we used the same weighing scales, containers, labels, and software to measure and record the food waste. We also used the same sampling days, sampling frequency, and sampling locations to ensure consistency and comparability. This step was carried out immediately after the end of the intervention, as the menu remained the same every 13 days, which means that were offered the same types of food and drinks in the same quantities and qualities. Additionally, this was done to avoid any confounding factors or external influences that could affect the food waste behavior of the students and staff. It aimed to assess the impact of the intervention on the quantity and composition of the food waste in the school canteen. Then, we calculated the following indicators for each type of food waste: the total wasted food, the quantity of carbon dioxide (the amount of carbon dioxide emitted from production to consumption), the water footprint (the volume of green, blue, and grey water consumed or polluted), the economic cost, and the caloric value.

Statistical analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS) version 16 (SPSS Inc, Chicago). The Kolmogorov–Smirnov test was employed to assess the normal distribution of variables. To statistically compare quantitative variables between the two phases of the study, we used the paired t-test and the paired samples Wilcoxon test. Additionally, *P*-values less than 0.05 were considered statistically significant.

Results

Food waste quantification

This study involved 300 students, corresponding to 26 monitored meals. On average, 147.26 g/per person of food remained unconsumed at the end of the lunch. The mean quantity of avoidable food waste in total during the first and third phases of the study, each lasting 13 days, was 17.96 and 15.52 kg per day, respectively. Table 1 shows the mean and standard deviation of food waste per person before and after the intervention, as well as the percentage reduction and the p-value for different food items. Overall, the mean total food waste before and after the study was 60.65 g/per person and 50.73 g/per person, respectively. There was no significant difference between the averages of food waste before and after the study ($P=0.397$). Moreover, the p-value was non-significant for all items. Although the p-value was not significant, there was a reduction in the waste of all the food items, with legume waste reduction being the largest.

Energy and price quantification

Table 2 shows the price and energy content of wasted food. The cost of wasted food decreased by 30.14%, and energy content declined by 31.65%. The food that was

Table 1 Mean initial serving and mean plate waste of 300 students in baseline and after the intervention (per person)

		Percentage reduction	P-value ^a
Rice			
Before	10.91 ± 6.88	22.73	0.324
After	8.43 ± 5.60		
Meat			
Before	13.60 ± 9.53	34.33	0.158
After	8.93 ± 4.60		
Bread			
Before	44.13 ± 40.60	17.67	0.369
After	36.33 ± 58.61		
Vegetables			
Before	16.91 ± 21.61	1.30	0.457
After	16.69 ± 13.11		
Legumes			
Before	1.43 ± 2.37	66.43	0.285
After	0.48 ± 0.83		
Potato			
Before	2.41 ± 5.38	26.97	0.628
After	1.76 ± 4.55		
Total			
Before	60.65 ± 26.04	16.35	0.397
After	50.73 ± 15.81		

^a Independent Samples Test was done for parametric data and Mann–Whitney Test was used for nonparametric data

Table 2 The price and energy of the wasted foods in baseline and after the intervention

				Reduction percentage
Price (Rial)				
Before	25079260	After	17947570	30.14
Before/person	637.01	After/person	445.01	
Energy (kcal)				
Before	240351.2	After	168279.1	31.65
Before/person	61.04	After/person	41.72	

wasted over the nine months when students dined on campus could feed an average of 1663 people, each consuming 2000 cal. In the first phase of the study, 120 people could be fed with the food that was wasted, and this number decreased to 84 after the intervention, resulting in 36 meals saved from being discarded. According to the estimates, the cost of year-long food waste in this faculty, based on the pre-intervention pattern, is equivalent to the salary of a manual worker in Iran for 17 months (The average wage of a manual worker is assumed to be 20000000 IRR per month).

Environmental impact

Table 3 shows the environmental effects of food waste in the canteen, including the total amounts of CO2 emissions and water. The p-value is non-significant for all items except for grey water ($p=0.033$). Moreover, the campus emitted an average of 615674.9 g CO2 equivalent greenhouse gas per day due to food waste. Apart from CO2 emissions, which increased slightly (0.06%), total water waste, blue water, grey water, and green water waste all decreased. The total amount of water waste as a result of food waste on the campus during the nine months when the students dined in the canteen from farm to table was 6661.24 m³.

Qualitative result

Based on the semi-structured interviews, the main causes of food waste in the canteens as perceived by the students ($N=20$) were determined. They believe that low-quality meals, unpleasant taste, large portions, and a limited menu, respectively, are the causes of food waste. The main cause of food waste as perceived by the university system is beyond of the students' control. (Fig. 1).

Discussion

The main purpose of the present study was to measure the amount of food waste in the canteen and to implement an intervention to reduce it. We also hypothesized that the intervention would reduce plate-waste. The

Table 3 Total environmental impacts of the food waste of 300 students in baseline and after the intervention

				Percentage of change	P-value ^a
CO ₂ (g)					
Before	615674.9	After	621519	-0.06	0.997
Before/person	157.63 ± 87.76	After/person	157.74 ± 80.57		
Total water (m ³)					
Before	481.09	After	433.07	16.66	0.456
Before/person	122.19 ± 0.04	After/person	107.38 ± 0.04		
Blue water (m ³)					
Before	98.04	After	103.36	0	0.862
Before/person	0.02 ± 0.0	After/person	0.02 ± 0.01		
Grey water (m ³)					
Before	43.75	After	25.69	12.5	0.033
Before/person	0.01 ± 0.0	After/person	0.006 ± 0.0		
Green water (m ³)					
Before	339.29	After	304.01	40.00	0.584
Before/person	0.08 ± 0.04	After/person	0.07 ± 0.04		

^a Independent samples test was done for parametric data and Mann-Whitney Test was done for nonparametric data

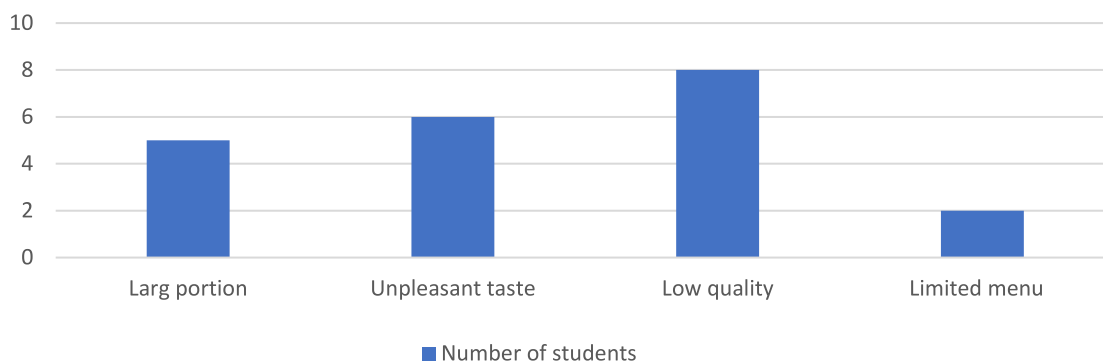


Fig. 1 The main causes of food waste in the canteens based on student’s interview (N=20)

study results showed that food waste was relatively high in the canteen and had significant environmental and financial consequences.

The reduction in food waste observed between the baseline and post-intervention periods was not statistically significant. It seems that continuous interventions may be needed to achieve a significant reduction in plate-waste over time.

In the present study, the total amount of food waste was estimated to be (mean=60.65 g/person). A study in Iran reported that each person wasted about 27.6 kg of edible food annually, and households with better food consumption management had a lower level of food waste [35]. Another study in the university canteens showed that the total food waste amount was 246/75 t/a [36]. Regarding the types of wasted food, bread was more frequently wasted than rice products. Mohammadi et al. suggested that this might be due to the preference for fresh bread in

Iran, as the quality of the bread deteriorated upon cooling down [37]. Vegetables were the second most wasted food category. A pilot study conducted by Abadi et al. in Iran also confirmed that staple foods and vegetables were the most commonly wasted food items [38]. Food waste in Western universities had similar characteristics. Rajan et al. found that in Northern British Columbia University in Canada, grain-based waste accounted for the largest proportion of food waste (28%), followed by raw fruits and vegetables (20%) [39].

Our results also revealed that the campus emitted an average of 615674.9 g CO₂ equivalent greenhouse gas due to food waste. The mean waste of livestock and poultry meat by university students accounted for only 13.60 g (per person) of food waste. Meat production and consumption have a significant impact on greenhouse gas emissions. Therefore, reducing meat consumption and waste and promoting a balanced diet are important

strategies for fostering ecologically sustainable consumption and enhancing students' nutritious diets [40]. Given that on average, it takes 3 kcal of fossil fuel energy to produce 1 kcal of food on the farm (before accounting for energy requirements for food processing and transportation) [41], the annual food waste in the faculty canteen is responsible for 9983821 kcal of fossil fuel energy. The intervention resulted in a 29.98% or 30% reduction in fossil fuel use (from 721053.6 kcal in the first phase to 504837.3 kcal in the third phase, which was after the intervention).

Avoidable food waste accounts for approximately 20% of the European environmental footprint. Reducing waste of all food items, such as bread and rice, has significant positive effects on the environment, mainly due to the large mass of the waste generated [42]. A study conducted in America, which examined the environmental impact of increased food waste, found that 25% of freshwater was wasted due to food waste [41]. Similarly, a study measuring the carbon footprint of supermarket food waste reported a total carbon dioxide waste of 2500 t CO₂e [43]. Furthermore, a national-level study reported that the amount of (green plus blue) water footprint ranged from 5938 to 8508 km³/year and it would increase by up to 22% by 2090 [44].

According to a semi-structured interview, the low quality of food was a major factor in food waste, as it was not appetizing. The quality of raw materials, such as meat, legumes, and vegetables, was poor. Beans and meat were undercooked, and the food lacked visual appeal. It also had an unpleasant smell and taste. A study suggested that improving food quality and taste could reduce food waste [45].

Surprisingly, the intervention, which was mainly educational, did not reduce food waste significantly. However, there was a considerable decrease in the waste of all food items. The intervention also reduced the percentage of water waste, with only the decrease in grey water being statistically significant. CO₂ emissions stayed relatively constant throughout the study.

Educational campaigns that focused on strengthening beliefs about the environmental consequences of food waste and empowering students have been shown to be effective in reducing food waste [46]. Therefore, such campaigns should be implemented on campus, especially targeting incoming freshmen. In a study involving 540 students living in residence halls and participating in a meal plan, broadcasting prompt-messages led to a 15% reduction in food waste among students [47]. This result is consistent with our results, which showed a 16.35% decrease in food waste. Although the overall reduction in food waste was not statistically significant, it led to a 30.14% reduction in expenses and a 16.66% reduction in

total water waste. The reduction in food waste also saved 41.72% of calories. Moreover, it is worth noting that our intervention mainly used social media, posters, and electronic interaction, which might not be as effective as face-to-face interventions [48].

Although low food quality was a significant cause of food waste on the campus, there were several other contributing factors. For instance, aspects of food safety and family standards played a pivotal role in food consumption and waste behavior [49]. A study suggested that taste, smell, flavor, and texture of food were associated with food waste behavior [45]. The findings of our study aligned with these causes of food waste. The students' personal feedback indicated that chicken had the lowest quality and the worst taste. This underscores the importance of food standards and sensory perceptions in influencing food waste behavior. While this issue was crucial, we could not address it fully because our intervention was mainly educational, and we did not intervene in the ingredients, the recipe, or cooking.

Despite the reduction in food waste, most of the changes in our study were not statistically significant, and there could be several reasons for this. One possible reason is that the intervention lasted for a relatively short time, which might not have been enough to lead to drastic changes in food waste behavior. A study conducted in primary schools in Porto found that short-term results from an educational intervention were only observed in children, whereas a significant decrease in food waste among teachers was observed in the long-term [21]. Since our target population was adults, expecting an immediate decrease in food waste might not have been realistic. Achieving a complete reduction of avoidable food waste is unlikely within a short-term or mid-term timeframe [42]. To reduce the amount of food waste in university canteens, canteens should offer smaller servings of the main meal and smaller dishes. Additionally, canteens could introduce tiered pricing for different portion sizes to discourage students from blindly choosing large portions when both large and small portions have the same price [50].

Large portion sizes can contribute to more food waste [51]. In the canteen, food is provided in large portions (approximately 555 g), which is a significant factor in food waste. Along with most meals, optional soups and salads are available. Although these are optional, many students choose to include them, often without the intention of consuming them, which further contributes to food waste. Our intervention included serving bread, which was previously wasted in large quantities, in smaller pieces, resulting in reduced bread waste. However, this did not mean that the students received smaller meals; they could still take as much bread as they wanted.

This approach successfully reduced waste. Similar studies have also shown that reducing portion sizes can help decrease waste [23, 52]. Additionally, extending the dining time to allow students more time to eat [53, 54], offering a menu with various choices [55, 56], and encouraging students to share food [45] can all help prevent food waste. One effective approach to reducing food waste is involving students in meal planning [21]. It is important to note that individuals who rely more on convenient food options and are less interested in food preparation are more likely to discard food. Therefore, campus food, which requires no preparation, is more likely to be wasted than meals prepared at home [17]. To effectively reduce food waste on the campus, it is essential to understand students' food waste behavior during the 'in-use' phase [49].

One of the challenges we faced during the intervention was persuading the students and workers that food waste could be reduced and had significant environmental consequences, reflecting their indifferent attitude toward the issue of food waste. Similar to our study, people often ignore the environmental consequences and carbon footprint of wasting food or when asked why they should reduce food waste [57].

The present study had several limitations. First of all, the intervention was only done in the short- and medium-term, as it was difficult to implement for a longer duration. According to other authors, it is essential to measure the impact at least 6 months after the intervention to assess behavior change retention and draw conclusions about its effectiveness [58]. Other limitations resulted from the fact that the food service operated a 2-week cycle menu, which might have introduced a bias into our results. Moreover, the limited face-to-face interactions with the students and the inability to improve the quality of food were other limitations.

A particular strength of this work is that we measured the impact of interventions at two different periods by weighing food rejected, which is the most accurate method for measuring plate waste. We weighed both original servings and plate waste for each participant [59]. In addition, we weighed all individual servings, and not just a random sample of initial servings, as done by other authors [60]. Moreover, analyzing the same menus at two different time-points gave us information about the outcome of the intervention, regardless of the effect associated with the menu type. Furthermore, by measuring food waste, we estimated some environmental consequences, such as CO₂ emissions and water waste. We measured food waste in the canteen of the campus, which might provide us with information about food waste that we could not observe at the household level. Wasting food in households occurs due to different factors, such

as meal preparation, food storage, and others, but at university, students deal with food in the edible state. Therefore, we cannot directly compare food waste in these two settings [57]. No similar studies on food waste in canteens were previously carried out in Iran.

Conclusions

In conclusion, this study casts a spotlight on the significant issue of food waste within the campus canteen, elucidating its profound environmental implications such as CO₂ emissions and water wastage, along with its economic consequences. Despite concerted efforts to mitigate food waste, our findings indicate that the reduction achieved was relatively modest. However, it is important to note that this study has yielded valuable insights into the underlying causes of food waste, including factors such as low-quality meals, an unpleasant taste, oversized portions, and limited menu options. Educational interventions emerged as a potential catalyst for reshaping student behavior and curbing food waste. By enhancing awareness, adjusting portion sizes, and improving the quality of food served, these interventions hold promise for affecting more substantial waste reduction. While the immediate impact of our study may appear limited, our study provides a useful baseline for future research on food waste in campus canteens, as it demonstrates the feasibility and challenges of conducting such research. We recommend that future studies use larger and more representative samples, cover longer periods of time, and test different types of interventions, such as incentives, feedback, nudges, or social norms. By doing so, we hope to generate more robust and reliable evidence on how to reduce food waste and its negative consequences.

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Author contributions

S.R.S and H.E.Z.: conceptualization, methodology, data curation and supervision. F.M.A, M.A, Z.B: data collection. M.A, S.F.F and S.R.S.: writing-original draft preparation, methodology, software and investigation. S.R.S: supervision, validation, writing-reviewing and editing.

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Availability of data and materials

The data used to support the findings of this study are available from the corresponding.

Declarations

Ethics approval and consent to participate

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved

by the Ethical Committees of the NNFTRI and the Faculty of Nutrition Sciences and Food Technology, Shahid Beheshti University of Medical Sciences. Written informed consent was obtained from all subjects.

Consent for publication

All authors read and are in support of article submission and publication.

Competing interests

We declare that none of us has a personal or financial competing interests.

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