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Original article

Food Waste Volume, Origin and Causes: Case Study in a Tunisian University Canteen

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Abstract

Food waste reduction strategy involves a quantification of food waste generation. This work aimed to evaluate the volume and the type of post consumption food waste and to identify its main causes in a university canteen (INAT, Tunis, Tunisia). Based on a direct method, wasted food was weighed with an electronic scale, during 23 working days. Three main food groups were quantified: prepared food (PF), plate waste (PW), which is the amount of food rejected by students and left on their plates, and non-served food (NS), which is the amount of food not distributed to diners and remaining in the serving bowls. Daily direct quantification has revealed that average meals served was 209 kg/day, whereas as average food daily waste was 15.90 % of PF, 0.074 kg per student and 13.4% of PF were non-served. The average index of waste/consumption was approximately 17 %, and classified as bad, and the per capita plate was 29.3 g. The daily quantities of food waste varied from 0 to 15 kg. The most rejected foodstuffs were stews (25.3%), pasta and cereal products (20.7%), and especially bread with a waste percentage of 43%. Cause and effect diagram coupled with interviews and survey allowed identifying principal causes for the food waste generation: perceived sensory quality, poor food presentation, poor menu planning and poor management of the fluctuation of the students' number (the quantities served were not adjusted) as well as customers' behaviours and habits. The cost of this food waste was estimated to 15.2% of the canteen annual budget. Potential interventions for food waste preventions are discussed.

Keywords: Food Waste reduction, Direct Quantification, Cause and Effect Analysis, Intervention, Students.

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INTRODUCTION

Food waste is a growing global burden, challenging food security, food safety, economy and environmental sustainability. According to the United Nations Environment Programme (2021), about 931 million tons of food were lost or wasted in 2019, representing 17 per cent of total global food production. Their economic, environmental and social implications have been recognized at the highest levels of global governance. Producing food that will be wasted requires water (losses of 250 km^3/year), land (28 % the world's agricultural area), energy, capital, fertilizers, and pesticides; and generates 8% of the global greenhouse gas emission (FAO, 2013). This carbon footprint of food waste has been estimated 3.3 billion tons of CO_2 equivalent per year. According to FAO (2013), one kilogram of food wasted further along the supply chain will have higher carbon intensity than at earlier stages. The total greenhouse gas emissions derive from power production machinery and transport vehicles, as well as from food waste decomposition itself (FAO, 2013).

Food waste is defined as a decrease in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers (Gustavsson et al., 2011). There is a clear distinction between food losses and food waste. However, both concepts are applied to lost and wasted food throughout the whole food supply chain; referred to as food that could have been used for human consumption. Food losses and waste amounts reached roughly US$ 680 billion in industrialized countries and US$ 310 billion in developing countries while about 820 million people are undernourished (FAO, 2013).

The issue of food waste reduction has become crucial for optimizing sustainable development and profitability, especially for low- and middle-income countries, since food waste control constitutes an important priority to ensure global food security. According to FAO (2013), the annual rate of food waste per individual is around 16% in the North Africa and Central Asia, 34% in Europe, 31% in Asia, 39% in North America and 11% in Latin America. Food waste takes place in low income countries during production processes, whereas in middle and high income-countries, in retails and consumers stages. According to the United Nations Environment Programme (2021), households have generated 61% of global food waste, whereas 26% of global food waste derived from food services and 13 % from retail. Shanes et al. (2018) have reported a negative correlation between the amount of food wasted and age. School and university canteens can thus constitute a privileged place and an educational potential to make students aware of nutrition and education on sustainability, thus impacting healthy and sustainable food production and consumption. In school and university canteens, food waste comes from two main stages: pre-consumption and post-consumption. The plate waste corresponds to both foods incompletely consumed as well as food served but untouched by the pupil or student (Buzby and Guthrie, 2002). Studies in school and universities canteens have shown that amounts of plate waste varied from 33 to 200 g per student (Ferreira et al., 2013; Falasconi et al., 2015; Silvennoinen et al., 2015; Gallardo

et al., 2016; Boschini et al., 2018). Food Service/Catering are responsible of 14% of the per capita food waste in the EU27 (excluding agricultural production). According to the Tunisian National Institute for Consumption (INC, 2017), 11 % meals prepared in Tunisian university restaurants are wasted, being the equivalent of US$ 1 million per year. In fact, a survey conducted by Ben Ismail et al. (2021) in a Tunisian university canteen has pointed out that 94% of respondents declared not finishing their plates.

Food waste in university dining halls can be affected by determinants such as the lack of attention to dietary habits, the menu composition, the rigid food procurement specifications, and the meal presentation (Falasconi et al., 2015; Ben Ismail et al., 2021; Richardson et al., 2021). In order to control and develop strategies to solve or at least reduce this problem, several tools have developed for evaluating and identifying causes of waste (Ferreira et al., 2013; Boschini et al., 2018). Derqui and Fernandez (2017) have reported how to evaluate food waste in school and university canteens: either directly by weighing with an electronic scale, or indirectly by visual estimation or questionnaires submitted to participants. Direct methods are considered as the gold standard, although the visual estimations could be a valid, reliable and time-saving alternative (Martins et al., 2014; Derqui and Fernandez, 2017). Buzby and Guthrie (2002) have estimated only the edible fraction of food waste since it leads to the loss of nutritional and economic values. The control of waste-consumption index allows optimizing the adequacy of prepared quantities in relation to consumption needs, food individual quantities as well as menus acceptance (Ferreira et al., 2013). Most of these studies have been performed in developed countries, where food cultures and habits, and meal catering services are different. In fact, according to Lorenz et al. (2017), behavioural, social and environmental factors could explain plate leftovers in a university canteen setting.

Food waste is prevalent in Tunisia (Sassi et al., 2016; Jribi et al. 2020): it represents 5% of food expenditures per year (US$ 197 million, INC). Per capita food waste reached 112 Kg/year in 2017 (Wang, 2019). In Tunisia, bread as well as dairy and cereal products are subsidised by a State compensation system. This compensation system aims to manage the prices of staple products, particularly cereal products, and to guarantee a regular supply of the local market by subsidised products at relatively stable prices, taking into account citizens' purchasing power (OECD, 2019). Therefore, the food waste has a direct impact not only on an environmental level but also on social and economic levels. Food waste reduction can contribute to strengthening the economic, social and environmental performance of the food value chain, and to improving food security. Food waste reduction strategy involves as a first step, to analyse the quantity, source and causes of waste.

The aim of this paper was to identify the volume and type of post consumption food waste at a Tunisian university canteen, using a direct quantification, and to determine its main causes, in order to recommend improvements and implement best practices towards food waste and sustainability in general.

MATERIALS and METHODS

Study site

The study was conducted at a canteen of The National Institute of Agronomy of Tunisia (INAT), a public school of engineers that belongs to the University of Carthage, Tunisia. The study was approved and authorized by the Head of the Restaurant. Canteen workers, chefs and director are public employees. The canteen uses the traditional meals production system "cook and serve". Meals distribution is made in trails by kitchen employees, without previous meals booking. The unit has a seating capacity of 500 and serves approximately 150- 300 customers, at very low prices (0.2 DT, less than US$ 0.07, through Tunisian state subventions). Meals are established under dieticians' supervision and are composed by soup, salad, main dish (chicken or turkey or stew), bread, and dessert (fruit or yoghurt or cheese).

Direct quantification of food waste

This study focused on post consumption food waste, i.e. all wasted food that could have been eaten if they had been prepared differently. Other biowaste, such as vegetable scrapings, peelings, coffee grounds, bones, or paper tissues, was not measured in this study. The methodology consisted in direct food weighing with an electronic scale as described by Hanson et al. (2016). Three main food groups were quantified, as illustrated in Figure 1.

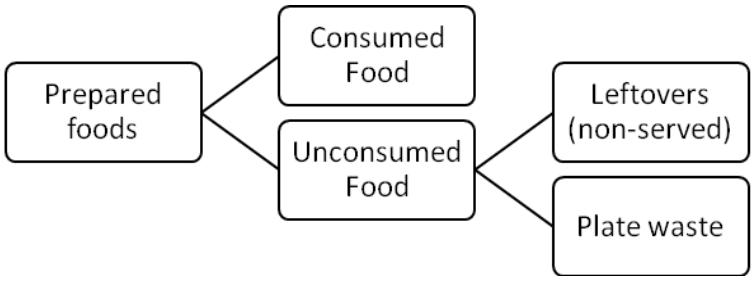

Figure 2. Main food groups quantified in the university canteen of INAT campus (adapted from Hanson et al., 2016).

Prepared Food (PF), Plate Waste (PW), which is the amount of food rejected by students and left on their plates and Leftovers or non-served food (L), which is the amount of food not distributed to diners and remaining in the serving bowls. Food is quantified at aggregated level, separated by dish type. The dish type classification for food waste collection reflects the typical structure of the Tunisian meal as described previously.

Plate waste index (PW) is calculated as the ratio between plate waste and the quantity of food consumed. This is an indicator of the quantity of meal wasted by users (Ferreira et al., 2013).

$$PW\ (\%) = PW/\text{quantity of food consumed} \times 100 \quad \text{(equation 1)}$$

Leftovers index (L) corresponds to the ratio between leftovers and the quantity of food consumed (Ferreira et al., 2013). It indicates the need of implementing actions to reduce waste and optimize productivity.

L (%) = L/quantity of food consumed x 100 (Equation 2)

The index of waste/consumption (%) corresponded to the ratio between plate waste and the quantity of foods distributed, subtracting the weight of leftovers (Ferreira et al., 2013). This indicates the relation between the waste returned by consumers at the end of the meal and the quantity effectively served, showing the interaction of consumer with the meal.

Cause-effect analysis for post consumption food waste generation

In order to identify causes of food waste, data have been collected via interviews with restaurant workers, chef, director and personal. In addition, face to face interviews based on a structured questionnaire, were carried out on 213 student respondents (mean age 23 years, 65% women) during one week. Questions addressed mainly food waste behaviours, eating behaviours and preferences, and evaluation of canteen food quality and environment. In order to highlight the main problematic areas, the identified underlying causes of food waste were grouped using the cause effect fishbone diagram (Ali and Avele, 2019).

Statistical analysis

Descriptive statistical analysis (mean, median, standard deviation, R^2) were determined using Microsoft Excel software.

RESULTS and DISCUSSION

The number of customers (students) served ranged from 128 to 264, with an average of 208, during the study period. A mean of 120 kg of food were prepared during the study period (Table 1) and 106 Kg of prepared food (88%) were served per day.

Table 3. Waste/consumption index and per capita plate waste during the study period (23 days)

Day	Number of served meals	Prepared foods (Kg)	Plate waste (Kg)	Leftovers index (%)	Waste/ consumption index (%)	Per capita plate waste (Kg)
1	128	43.0	10.0	26.5	29.4	0.078
2	178	140.0	25.5	23.9	22.6	0.143
3	206	85.4	8.5	15.2	11.5	0.041
4	218	140.0	18.5	8.9	14.4	0.085
5	177	94.0	16.0	27.0	21.6	0.090
6	240	314.0	18.0	4.7	6.0	0.075
7	179	105.0	22.0	14.8	24.0	0.123
8	195	58.0	7.0	19.6	14.4	0.036
9	162	312.0	27.4	11.2	9.8	0.169
10	230	95.0	15.5	11.8	18.2	0.067
11	161	111.0	15.7	20.7	17.1	0.098
12	263	104.0	13.0	17.5	14.7	0.049
13	242	138.0	23.2	11.3	18.7	0.096
14	253	63.0	10.0	20.5	19.1	0.040
15	241	126.0	34.0	14.2	30.8	0.141
16	231	63.0	7.0	8.6	12.1	0.030
17	194	140.5	23.0	13.8	18.6	0.119
18	267	95.0	5.5	4.4	2.2	0.007
19	196	75.0	11.0	13.6	16.7	0.056
20	212	117.0	24.5	10.4	23.1	0.116
21	199	91.0	10.6	13.8	13.3	0.053
22	219	143.0	17.0	10.9	13.2	0.078
23	205	115.0	20.9	16.2	21.1	0.102
Mean	208	120.3	16.7	14.8	17.1	0.080
Median	166	79.0	15.5	21.3	25.3	0.090
Min	128	43.0	5.5	4.4	2.2	0.010
Max	267	314.0	34.0	27.0	30.8	0.170
STD	35	67.2	7.8	6.1	6.8	0.040

About 13 Kg were not served per day and amounts of 16.7 kg were wasted per day, without any pattern or trend to the waste by day. This averaged was 0.081 Kg of food waste /student. Food waste mean and median are close, suggesting an approximately normal distribution. Weak relations were found between PF and per capita plate waste (R^2= 0.4052) and between PF and L values (R^2= 0.2674), but surprisingly no relation between PF and PW values (R^2= 0.0872). This plate waste index value of 15% of the amount of food served is considered as unacceptable, since above of 10% as defined Augustini et al. (2008). Our findings are in agreement, but in the lower range, with other studies in school and universities canteens (Ferreira et al., 2013; Falasconi et al., 2015; Silvennoinen et al., 2015; Gallardo et al., 2016; Boschini et al., 2018; Ali and Ayele, 2019). This can be partly explained by the

adequate portion size and the offer of a unique menu, in comparison with developed countries canteen systems. However, when compared to previous Tunisian study (11%; INC, 2017), the plate waste index found in our study (15%) was higher. Our results also indicate that 12 % of prepared food was lost because non-served. It was unexpected to find much cooked food to be wasted. This can be explained by the lack of booking system and the lack of planning. The director of the canteen estimated roughly the number of students and the number of meals was prepared consequently. Therefore, food service unit performance can be classified as bad as since the index of waste/consumption was about 17 %, above 15 % (Nonino-Borges et al., 2006). Plate waste is also a managerial issue of economic concern to restaurant/canteen operators. In our study, the cost of food waste and leftovers was estimated to 15.2% of the canteen annual budget. Figure 2 indicates the contribution of food categories in generation of plate waste and leftovers.

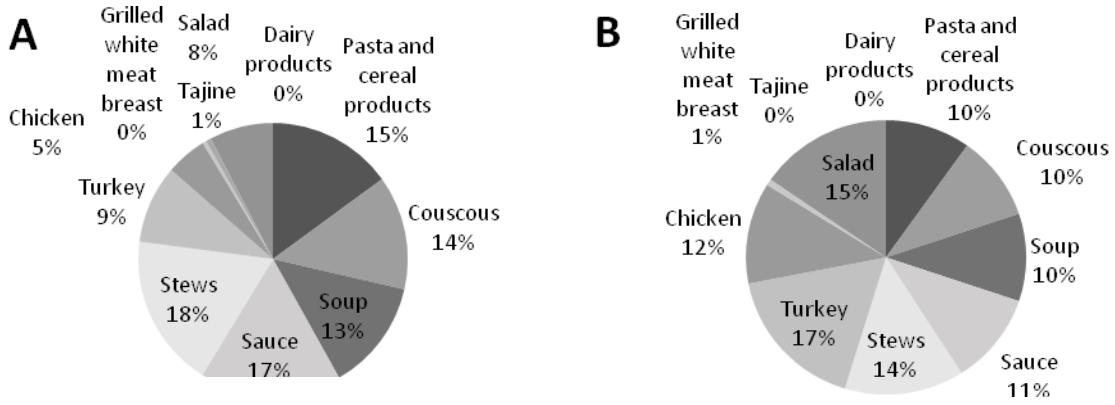

Figure 2. Contribution of food items to Leftovers (A) and Plate waste (B) in the university canteen

*Tajine: A Tunisian dish composed of a mixture of eggs, chicken, minced veal, tuna, potatoes, spinach, cheese, parsley and a mix of spices, cooked in oven. Couscous is a traditional Tunisian dish based on steamed semolina served with meat, vegetables and spices.

Turkey based dish, salad, chicken, based dish and sauce were predominantly wasted by customers, whereas tajine and dairy products were all consumed. Leftovers concerned mainly stews, sauce, pasta and cereal products (excluding bread). In contrast, poultry meat breasts and dairy products were served. Study of Ben Ismail et al. (2021) in a university canteen has shown that survey respondents declared to discarding mostly vegetables, stews, and soups. Food waste varied greatly according to the menu items (Figure 2). This variation should constitute an indicator that the item was not appreciated among the customers, and should be removed from the menu. Surprisingly, turkey and chicken based dishes were predominantly wasted by customers, although they are costly and interesting on the nutritional point of view. This can be probably explained by a poor sensory quality of these dishes. In fact, Wiriyaphanich et al. (2021) have established a negative correlation between students' satisfaction with the meal and food waste.

Bread is the major wasted food item with a waste/consumption index of 46% (Table 2).

Table 2. Bread waste in the university canteen during the study period (23 days)

Leftovers index (%)	6.7
Waste/consumption index (%)	46.3
per capita bread plate (unit)	0.834

Bread is the most essential food for people. However, considerable amounts of bread are either lost or wasted in Tunisia (INC, 2017). This was confirmed by our study with a waste/consumption index of 46% (Table 2), although only 7% of the survey respondents have evaluated the bread quality as low.

The main causes of the food waste and leftovers were identified through interview and structured questionnaire, and were grouped under six cause categories, namely materials, procedures, workers, policies, environment and customers (students), in order to highlight the main problematic areas and to develop potential food waste reduction strategies (Figure 3).

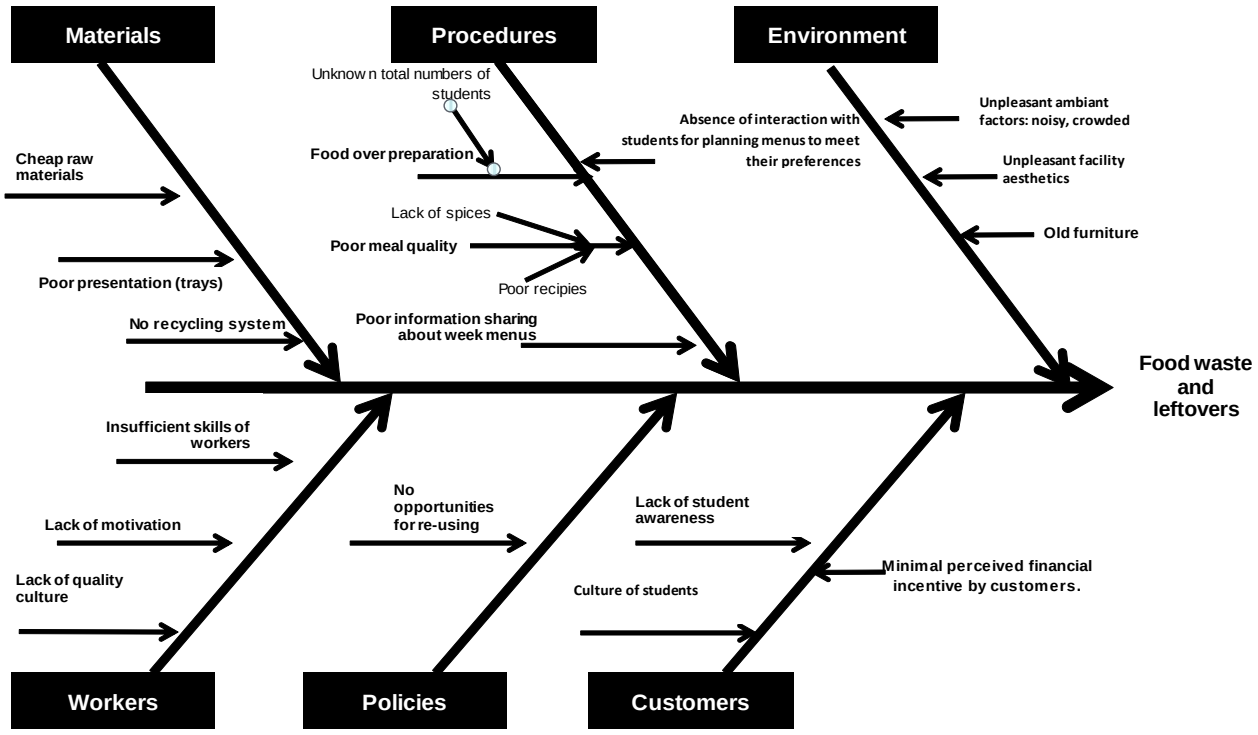

Figure 3. Causes and effects for post consumption food waste generation in the university canteen

"Materials" cause category analysis has shown several explanations for canteen food waste. Because of the very low price of the meal (thanks to Tunisian state subventions), only cheap raw materials can be bought and may be lower in quality. Food trays assisting staff and customers in conveniently carrying food are made up of iron: they are very bad looking and old, leading to unsatisfactory food presentation. After cooking and preparation, the food presentation is as important as

the food sensory properties (Wiriyaphanich et al., 2021). Logistical issues, such the absence of recycling system and food waste monitoring system, have also been pointed out.

"Procedures" cause category analysis has revealed through interviews, poor planning and forecasting procedures. Strict forecasting and planning are needed to ensure kitchen workers prepare and cook the exact amount of food daily. Over forecasting leads to throw food out at the end of the day, but under forecasting makes difficult to satisfy the needs of customers. In our study, food over-preparation was due to the absence of a booking system which determinates the daily number of customers. The number of customers served varied greatly from 128 to 264, with an average of 208. Our survey has revealed that meal quality was perceived as bad (30% of panellists) or medium (66%), due to a lack of taste (68%). Meal recipes and food preparation are in accordance with food health and safety regulatory standards, but without spices: their use is a distinctive feature of Tunisian cuisine. Therefore, menus did not meet customers' preference. Moreover, daily food waste variations were partly related to different menus: chicken and turkey dishes generated more waste than tajine or grilled chicken breasts. The portion size cannot be considered as a sub-cause of food wastage: only 7% of respondents estimated the size portion too large.

The investigation of "Environment" cause category was important, since customers' perceptions of the physical environment influenced disconfirmation, customer satisfaction and restaurant quality (Ryu and Han, 2011). Facility aesthetics are considered as unpleasant by customers as well as ambient factors such as noise and crowded. Restaurant tables and chairs are old and bad looking, then not inviting, and are not well arranged within the environment.

"Workers" cause category examination has pointed out significant problems of cooking skills and of service quality. Our survey indicated that 65% of respondents have noted a difference in meal taste and flavour, within a week. Concomitantly, we have observed that Team A generated 39% more food waste than Team B. The whole kitchen operations are dependent on the chef operational ability. Actions of unskilled and inexperienced employees would also cause food waste, such as not knowing how to cook food properly. Our study has clearly shown poor food quality service. Managing service quality must focus on both a customer and employee view. In fact, interviews have revealed a lack of motivation. Job satisfaction not only plays an important role on customers' perception of service quality (direct and positive impact) but also mediates the relationship between empowerment and service quality (Gazzoli et al., 2010).

The study of "Policies" cause category should be considered since redistributing non-served food to people or animals depends on food health and safety regulations. In Tunisia, there are no regulations; non-served food must be thrown out.

Finally, examination of "Customers" cause category led to address not only attitudinal factors regarding a person's principles, values and beliefs, but also routine regarding a person's established habitual behaviour. Our results are in agreement with those of Ferreira et al. (2013), Lazell (2016), Lorenz et al. (2017), Marais et al. (2017) and Reynolds et al. (2019). Interestingly, respondents have admitted that they are used to never (33%) and sometimes not to (33%) finish their plates at the canteen and to food waste habitual behaviour at home (40%). Ozcicek-Dolekoglu and Var (2019) have observed lower self reported food waste in Turkish University dining halls. Another customer related reason for plate waste could be also due to the typically cheap prices of menu items. The paid price of US $ 0.07 corresponds to french baguette price. As stated by Papargyropoulou et al. (2019), the least wasteful restaurants are those where the customers paid according to what they consumed. Other study cases in school and university canteens have pointed out factors of food wastage, such as number of meals served, the margin of error used during planning, the individual quantity of food defined, food workers training and the utensils used during plating (Falasconi et al., 2015; Silvennoinen et al., 2015).

Food production, wasted/lost or not, uses across its supply chain, fossil fuels for mechanical planting/harvesting, transportation and cooling purposes (FAO, 2013). Our study has determined that about 30.08 Kg of consumed or non-served food are thrown out daily, producing an average of 75.02 kg of CO_2-equivalentper day (FAO, 2013). Moreover, anaerobic decomposition due to the disposal on landfills emits methane, has 25 times the global warming potential of CO2 (FAO, 2013).In order to reduce environmental impact, several studies reviewed by Girotto et al. (2015) have developed food waste management options, such as the use for feedstock, composting, incineration, land filling, energy production by means of anaerobic digestion (e.g. bio-hydrogen or bio-methane productions) or the production of bio-plastics and bio-fuels together with the extraction of high-value components. In our study, in addition to the cost, variation in food waste production should be taken in account when implementing a future waste management plan in terms of capacity and flexibility. Therefore, for instance, production of bio methane would not a rentable option, whereas composting constitutes the most suitable approach for recycling canteen waste, which is composed mostly by organic waste (Cerda et al., 2018). Identifying the causes of food wastage allows reducing food waste and implementing lasting corrective actions. Actually, source prevention by reducing the amount of food waste or losses in the first place, constitutes the most preferred option for addressing food waste along the food supply chain (US Environmental Protection Agency, US EPA). Adequate forecasting and planning systems must be implemented to avoid having to throw food out as a result of over-production. New tools can be developed, like smart phone applications, where students had to pre-order the meals, they intended to eat every day. This could therefore help the kitchen chef to better plan the food production and avoid overproduction. Food redistribution to people or animals can be an interesting option but this is a policy-making issue. The European Commission has published guidelines on food donation (European Commission, 2017). There are actually no regulations on food donation and redistribution in Tunisia.

Food waste tracking and analytics can be a strategy option in reducing of food waste production (Burton et al., 2016). This tracking is useful to implement the most adequate corrective actions. In addition, separation and measurement of food waste by kitchen employees lead to a better awareness of the amount of food waste they are generating, which in turn provokes efforts to reduce food waste (Derqui and Fernandez, 2017). Informing customers about the amount of food waste produced each day can also be helpful to increase their awareness (Gustavsson et al., 2011). For instance, our laboratory is currently evaluating the effect of implementation in the dining hall, a bread "wastemeter": this large transparent jar was designed to measure the quantity of bread wasted and therefore to visually raise students' awareness of waste. Preliminary results were promising and indicated a reduction in levels of bread waste.

Post-consumption food waste can be reduced through better food presentation, understanding customer needs and improving quality service. This could include observing the types of food that come in on customer plates and adjusting the menu accordingly. Ben Ismail et al. (2021) have pointed out a relationship between perception of food quality and food presentation. Richardson et al. (2021) have suggested adapting plate shape and size could be included into waste reduction strategies in university dining halls. Competence and professional skills in food preparation and palatability play a key role in the prevention of food waste. Adapting recipes to customers' preferences by adding spices for instance, and improving preparation techniques for the commonly wasted food products can help to reduce food wastage (Papargyropoulou et al., 2016). This would be achieved by an extensive training to gain culinary foundation and understanding. Fereira et al. (2013) have established food waste as an index of food service quality. Aschemann-Witzel et al. (2015) has shown that improving service quality can lead to a decrease in food wastage. Job satisfaction and empowerment of employees are two factors influencing service quality (Gazzoli et al., 2010). Empowerment is more and more involved in the managerial practices used in the service industry. In fact, empowering workers has been shown to improve organizations' productivity and performance (Gazzoli et al., 2010) and should be helpful in reducing food waste. It is also necessary to provide to kitchen employees and chef, training on how to prevent food waste.

Our study has identified customers' behaviours and habits as a cause of post consumption food wastage. Aschemann-Witzel et al. (2015) have reported three general consumer-related factors: social factors, such as household type, family stage and related lifestyle, individual behaviours and perceptions and expectations towards foods, and customers' lack of awareness, knowledge and skills. These individual behaviours can be modifiable through information and strengthened awareness. Therefore, it is crucial to educate customers to promote the importance of food waste prevention in terms of environmental, social, and economic impacts, and more specifically to only take what they need and eat all the food on their plates. Interestingly, times of crisis such Covid-19 led to an increased awareness on

food waste prevention (Jribi et al., 2020; Ben Ismail et al., 2021). Case studies of food waste reduction interventions in universities have exhaustively reviewed by Reynolds et al. (2019) and have led to mixed results. Nevertheless, awareness campaigns (Pinto et al., 2018; Ellison et al., 2019), simple message-type intervention encouraging pro-environmental behaviour (Whitehair et al., 2013) and a social media-based intervention (Lazell, 2016) have given promising results.

CONCLUSION

The first step to implement a food waste management plan at University restaurant consisted in determining the quantity, the composition, and the distribution of the waste generated in its facility. Our study has indicated not only an unacceptable level of plate waste (15% of the amount of food served), but also a bad food service unit performance since the index of waste/consumption was about 17%. However, our approach does not provide insight into total waste, but only in the post consumption stage. The post consumption waste was the result of a lack of planning management, poor food presentation and sensory quality related to poor cooking skills, as well as customers' consumption behaviours. The canteen has to gradually move towards more of a preventative approach to food waste. We strongly recommend to implement planning and forecasting procedures, including a booking system for the students and monitoring food waste, as well as to launch education and awareness campaign for customers and for canteen employees. Standards of service quality and physical environment must be also improved in order to maximize customer satisfaction, and consequently reduce food wastage. As FAO suggests, reducing consumers' food waste may improve their food availability and access, in addition to that of possible direct beneficiaries of food redistribution schemes. Reducing food loss and waste is critical to reaching the world's Sustainable Development Goals, especially "End Hunger" and "Ensure sustainable consumption and production patterns". These food wastes and losses can be also reused in different alimentary and non-alimentary ways. Our laboratory has recently contributed to develop a novel potential bio-based rejuvenator for recycled asphalt pavement (Nciri et al., 2020).

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