Development of a food waste prevention strategy: a case study in a hotel in Eastern Morocco

Abdelouadoud Omari[1*], *Abdelhafid* Chafi[1], *Ouafae* Mokhtari[1], *Linda* Zraibi[1], *Ikram* Azzakhnini[1], *Boumediene* Ben Cheikh[2], *Kaoutar* Mchiouer[1], *and Ouahid* El Asri[3]

[1] Laboratory of Agricultural Production Improvement, Biotechnology and Environment, Faculty of Sciences, Mohammed First University, Oujda, Morocco
[2]Laboratory of Applied Geosciences, Faculty of Sciences, Mohammed First University, Oujda, Morocco
[3]Microbial Biotechnology and Plant Protection laboratory, Ibn Zohr University, Agadir, Morocco

Abstract. The present work concerns the development of a food waste prevention strategy in a restaurant operating within a hotel in the city of Saidia in Eastern Morocco. The food service sector was chosen for this study because it is the second highest contributing sector to food waste on the global scale. Therefore, the role it plays in environmental pollution should not be neglected. The food waste prevention strategy adopted in this work consisted in performing a food waste audit at first. Then, the purchasing, storage, and handling conditions of food were improved. Finally, waste sorting was performed. The average daily food waste generated by the case study restaurant was 320.3 kg/day. The highest amount of average daily food waste (166.7 kg/day) was generated during food preparation, while storage waste had the lowest amount (30.1 kg/day). The most wasted food commodities were vegetables (50.8 kg/day), fruits (47.1 kg/day), sauces (39.9 kg/day), and cereals (38.4 kg/day). While the least wasted food commodities were eggs (10.2 kg/day) and dairy products (11.7 kg/day). The majority of the food waste generated in this study was avoidable, and fish and seafood were the food commodities with the lowest Eco-efficiency (high cost – high waste). The food waste percentage decreased from 35% to 20% within approximately 4 months following the execution of the food waste prevention strategy. **Keywords:** eco-efficiency, environmental pollution, food service sector, food waste.

1 Introduction

It is important to satisfy the demand of the growing human population for food whilst also making sure that the impacts of food production on the environment are also taken into consideration because half of the world's habitable land is exploited for agriculture [1], which plays a role in transforming habitats [2,3] and can pose a threat to biodiversity [4]. Food production is also responsible for 25% of global greenhouse gas emissions [5] as well as excessive water use [6].

Food waste is also a growing concern because it is estimated that one-third of the food produced worldwide is wasted [7]. Parfitt et al. [8] defined food waste as the "wholesome edible material intended for human consumption, arising at any point of the food supply chain that is instead discarded, lost, degraded or consumed by pests." According to the Food Waste Index Report of 2021 [9], 60% of food wasted annually comes from households, followed by the food service sector with 26%, and the retail sector with 13%. According to the same report, the amount of food wasted annually in Morocco is about 3.3 million tonnes [9].

Food waste can have several adverse impacts on the environment. First of all, a 2018 study by Poore and Nemecek [10] estimated that food wastage accounts for about 6% of total global greenhouse gas emissions. In addition, eutrophication, which means the enrichment of bodies of water in nutrients such as phosphorus and nitrogen, can also be caused by food waste, as demonstrated by Grizzetti et al. [11] in a study establishing a link between food waste and the amount of nitrogen in water causing eutrophication, thus leading to excess algae growth, water hypoxia, and fish kills. The global economic cost of food waste is about USD 1 trillion each year [12]. Thus, based on all the aforementioned problems, food waste prevention can be beneficial for the environment.

The objective of this work is the contribution to the development of a food waste prevention strategy in a hotel in the city of Saidia in Eastern Morocco because, on one hand, the food service sector is the second highest contributing sector to food waste on the global scale, therefore, the role it plays in environmental pollution shouldn't be neglected. On the other hand, food waste prevention would allow the hotel concerned with the study to reduce the costs associated with wasted food.

* Corresponding author: omari_abdelouadoud1718@ump.ac.ma

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (http://creativecommons.org/licenses/by/4.0/).

2 Material and methods

2.1 Methodology approach

This work was carried out during the period between June and August of the year 2021, and July 2022, in a restaurant operating within a hotel in the city of Saidia in Eastern Morocco. The restaurant specializes in various styles of cuisines and offers two food service types consisting of buffet style and a la carte' for all three main meal times (breakfast, lunch, and dinner). The main restaurant of the hotel and the five kitchens/food preparation areas associated with it were concerned by the study. The restaurant serves food to an average of 444 customers per day. The methodology used in this study for food waste prevention (Fig. 1) can be described as follows: 1) waste audit to determine the origins, quantities, compositions, and types of food waste as well as to determine the influence of food service style and customers on waste generation, 2) improvement of purchasing, storage, and handling conditions of food, 3) waste sorting to facilitate waste recycling.

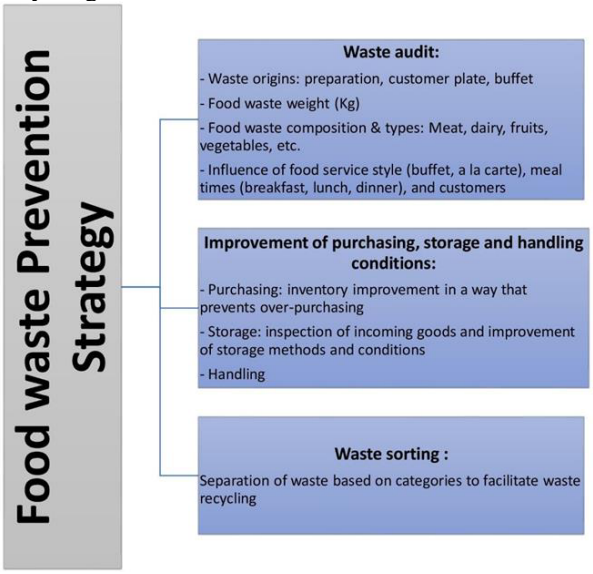

Fig. 1. The strategy developed for food waste prevention.

2.2 Food waste audit

The first step of the food waste prevention strategy consisted of conducting a food waste audit. A food waste audit is a valuable tool in terms of informing businesses about the sources and reasons behind food wastage and identifying inefficiencies within their practices in the interest of addressing each deficient operation resulting in food wastage and ideally work on improving it [13].

The food waste audit was performed based on the conceptual framework for the study of waste generation developed by Papargyropoulou et al. [14]. The origins of food waste were divided into four main categories, i.e., storage waste, preparation waste (peeling, cutting, overcooking, etc.), buffet leftover waste (excess food that was displayed to the customers during the buffet service and wasn't consumed by them) and plate waste (food that was served to the customers and was left uneaten), according to how the literature usually categorizes them [15,16]. The amount of food wasted from each category (in kg) was weighed at the source using a digital scale. The visual observation allowed the separation of waste into avoidable waste, which means edible waste (e.g., leftovers), and unavoidable waste, which means non-edible waste (e.g., peels, bones, etc.) [17] because we were also interested in learning which processes produced more unavoidable waste and which processes produced less avoidable waste and vice versa. The influence of the food service style (buffet and a la carte) was considered in the food waste audit for the purpose of introducing comprehensive changes based on the results obtained. The influence of customers on food waste generation was also assessed, on one hand, to determine if the number of served customers per day would increase or decrease the amount of generated waste, and on the other hand, to study the variations in the daily food waste generation per customer, to try to detect patterns allowing for potential corrective measures to be implemented. Finally, the food waste composition was determined. It serves to facilitate performing an Eco-efficiency analysis i.e., the determination of which food waste fraction is significant in terms of weight and which food waste fraction is significant in economic terms [14]. The eco-efficiency of the different food commodities was determined by matching the cost parameter (Moroccan Dirham/kg) to the environmental parameter (percentage of food wasted). This approach allowed us to distinguish between three Eco-efficiency categories: low eco-efficiency food (high cost – high waste group), medium eco-efficiency food (high cost – low waste group or low cost – high waste group), and high eco-efficiency food (low cost – low waste group). The food waste composition (Table 1) was divided into the following food commodity categories: Cereals, Dairy, Eggs, Fish and seafood, Fruits, Meat, Oils, Poultry, Sauces, and Vegetables. The food waste audit took place for a period of one week, to take weekly variations into account.

Table 1. Food waste categorized by types of food commodities.

Food commodity category	Food type included in each food commodity category
Cereals	Flour, bread, pasta, rice, pastries, wheat, and oat products
Dairy	Milk, cheese, yogurt, ice cream, and other dairy products
Eggs	Eggs
Fish and seafood	Freshwater fish, demersal fish, pelagic fish, other marine fish, crustaceans, cephalopods
Fruits	All fruits
Meat	Bovine meat, ovine meat, offal, and other meat
Oils and fat	Olive oil, butter, and other vegetable oils
Poultry	Poultry meat
Sauces	All premade and prepared sauces, including salad dressing and canned soup
Vegetables	All vegetables including potatoes

2.3 Assessment of the methods and conditions of purchasing and storing food

The methods and conditions of food reception and storage in the hotel were assessed to introduce corrective measures in case of the detection of anomalies. First of all, the daily food reception registers were checked to obtain information on the following data: the quantities delivered, the quality of the food received (maturity, appearance of fruits and vegetables, packaging, etc.), labeling (in particular the expiry dates and the best before dates of the products received), and the temperatures of received food (Table 2).

Table 2. Examples of food storage temperatures [18].

Product	Maximum storage temperature
Frozen food	-18°C
Fish, molluscs, and crustaceans	2°C
Meat and ground meat	3°C
Red and white offal	3°C
Pasteurized milk, cheeses, and creams	6°C
Raw fruits and vegetables	from 8°C to 10°C
Prepared meals/ready meals	- refrigerated: 3°C - heat preserved: >65°C
Other foodstuffs	The temperature indicated on the food packaging

Reception control is a crucial step in terms of reducing food waste by ensuring that only foodstuffs whose hygienic conditions are satisfactory are accepted. The financial records and food purchase inventory were checked as well.

In addition, after having checked that the food received is of satisfactory hygienic quality, it is necessary to ensure that this hygienic quality is preserved by ensuring that the storage conditions of food are controlled. Thus, the conditions and practices for storing food were checked in the dry storage area, as well as the positive and negative temperature cold rooms. Each of the hotel's food preparation areas has a positive temperature cold room (food stored between 0 and 10°C) and a negative temperature cold room (food stored below 0°C). The criteria of food storage are shown in Table 3 for the dry storage area, positive temperature cold room, and negative temperature cold room.

Table 3. Food storage criteria.

Area	Storage criteria
Dry storage area	Absence of food stored at incorrect temperature and humidity Products of different categories are properly identified and separated from each other Storage according to the First-in-first-out (FIFO) policy Absence of toxic substances Absence of expired food Absence of food placed directly on the floor Adequate hygienic condition
Negative and positive temperature cold rooms	Adequate storage temperatures Adequate separation of products Absence of expired food Products are properly protected and identified Suitable food containers Absence of food placed directly on the floor Storage according to the First-in-first-out (FIFO) policy Adequate hygienic condition

The purpose of the food storage criteria listed in Table 3 is to prevent 3 sources of food contamination. These sources of contamination are physical, chemical, and biological [19]. Regarding the storage of food in the dry storage area, the "absence of food stored at incorrect temperature and humidity" criterion means that the temperature and humidity in this area must be controlled in a way that does not allow the temperature to exceed 25°C and the humidity to exceed 60% (value beyond which mold begins to grow) [20] to prevent biological hazards, i.e., the development of bacteria and mold. As a result, we checked the temperature monitoring log of this area and the availability of a functional extractor and a hygrometer (to record variations in humidity).

The "products of different categories are properly identified and separated from each other" criterion means that, on one hand, the cardboard packaging of the products must be removed to prevent physical and biological dangers resulting from dirt which may be found in the boxes and/or the introduction of pests (insects or rodents) into the boxes. On the other hand, this criterion means that the products must be grouped by product category. As a result, we checked to see if the products were properly identified by category and that a product unboxing area was designated.

The "storage according to the First-in-First out (FIFO) policy" criterion means that the goods acquired first must leave first for the food stored to not exceed its expiry date or best-before date [21].

The "absence of toxic substances" criterion means that food should never be stored next to chemicals to prevent chemical hazards. As a result, we proceeded to verify that there was an area dedicated solely to the storage of chemicals and that it was situated far from the dry storage area.

The "absence of food placed directly on the ground" criterion means that a distance of at least 15 cm between the ground and the food must be kept to prevent physical and biological hazards resulting from the introduction of pests.

The “adequate hygienic condition” criterion means that the dry storage area must be cleaned properly, so we proceeded to check if a cleaning and disinfection plan for this area was implemented and regularly followed. Physical hazard prevention is ensured by cleaning (use of detergents), while biological hazard prevention is ensured by disinfection (use of disinfectants).

As for the positive and negative temperature cold rooms, the "adequate storage temperatures" criterion means that the temperature monitoring logs of the cold rooms should be checked to ensure that the temperatures are suitable for the storage of the various products, to prevent biological hazards (development of microorganisms in food).

The "adequate separation of products" criterion means that the cardboard packaging of the products must be removed to prevent physical and biological hazards. It also means that the products must be stored in a way that prevents cross-contamination that may result from biological hazards (microorganisms). For example, clean products (e.g., meats) should be placed on the top shelves while dirty products (e.g., raw fruits and vegetables) should be placed on the bottom shelves.

The "products are properly protected and identified" criterion means that each product stored in cold rooms must be suitably protected (e.g., by using cellophane paper) and labeled (on the labeling, the dates of use and expiry dates must be mentioned) to prevent biological and chemical hazards (microbial growth and cross-contamination by allergens). As a result, we proceeded to check if the products stored in the cold rooms were properly protected and labeled.

The “absence of food placed directly on the floor”, “storage according to the FIFO policy” and “adequate hygienic condition” criteria were analyzed based on the same principles described for the dry storage area.

2.4 Assessment of food handling conditions

To avoid food waste resulting from poor food handling practices, the food handling practices in the kitchen/food preparation areas of the hotel were monitored. As a result, the hygiene of the staff handling food (the proper wearing of kitchen uniform; proper and regular washing of hands before, during, and after food handling; no wearing of watches or jewelry) was monitored. These measures allow the prevention fromphysical, chemical, and biological hazards.

To prevent chemical and/or microbiological hazards from occurring because of the cross-contamination of food (microorganisms and allergens), we proceeded to check the availability of color-coded cutting boards for each food category (e.g., red cutting board for red meats, white for poultry, blue for fish, etc.). We also proceeded to verify the absence of wooden utensils and utensils in poor conditions to prevent biological hazards since wooden utensils contain porosities that facilitate microbial growth [22]. The hygienic condition in the different food preparation areas (cleanliness of the areas and the equipment) was checked and the cleaning and disinfection records were monitored.

2.5 Waste sorting

The last step in the development of the food waste prevention strategy consisted in setting up a waste sorting system in the hotel. The purpose of this system is to allow food waste which the previous steps could not eliminate to be valorized. Food waste is considered organic waste which can be valorized by anaerobic digestion for the production of energy (for example, production of biohydrogen or biomethane) [23], or by composting which can be carried out either to recover nutrients or as a carbon sequestration process, through the formation of humic substances [24].

The hotel's kitchen staff was trained in waste sorting by a certified trainer, and bins dedicated only to organic waste have been installed in food preparation areas. Waste was sorted into the following categories: plastic, cardboard, and metal packaging in a yellow waste bin; food waste in a red waste bin; glass packaging in a green waste bin; and papers in a blue waste bin. After the end of each day, the organic waste put in the red waste bins was collected from the food preparation areas and put in a large dumpster in the waste room. It should be noted that the cooking oil was disposed of in a large container that is specifically dedicated to it and that this container was labeled and also placed in the waste room. A company specializing in the collection of cooking oil makes regular visits to the hotel to collect it.

3 Results and discussion

3.1 Food waste audit

The results of the quantification of food waste generated from storage, preparation, and serving customers (buffet style and à la carte’) are presented in Table 4. Based on Table 4, the average daily food waste generated by the case study restaurant was 320.3 kg/day. The highest amount of average daily food waste (166.7 kg/day) was generated during food preparation, while storage waste had the lowest amount (30.1 kg/day).

In a study about food waste conducted by Papargyropoulou et al. [14] in a hotel restaurant, the highest amount of average daily food waste was also generated during food preparation. This implies that food-handling practices within these types of establishments could benefit from concentrated efforts aiming to optimize them in a way that avoids excessive waste. The average daily food waste recorded for the buffet (67.9 kg/day) was higher than the average daily food waste recorded for customer plates (55.5 kg/day). Other authors [15,25] also found that the buffet style was more wasteful than ‘a la carte’.

Based on our observations, this is due, on one hand, to customers taking more food than they can eat from the buffet, and on the other hand, to the kitchen staff usually preparing more food for the buffet in case more guests than the expected amount shows up to an event for example. In general, the amount of total daily food waste increased with the number of customers served, and vice versa, because the highest amount of daily food waste was recorded on Sunday (400 kg), which also had the highest amount of customers served (512 customers), while the lowest amount of daily food waste was

recorded on Thursday (229 kg), which also had the lowest amount of customers served (402 customers). The average daily food waste per customer was 0.72 kg/customer, and in a similar way to total daily food waste, this amount also increased with the number of customers served and vice versa.

Table 4. Average daily food waste categorized by food waste origins.

	SunDay 1	MonDay 2	TueDay 3	WedDay 4	ThurDay 5	FriDay 6	SatDay 7	Daily average	Standard deviation
Storage waste (kg)	20	23	11	56	10	67	24	30.1	20.6
Preparation waste (kg)	233	192	144	137	104	161	196	166.7	40.09
Buffet leftover (kg)	78	72	65	67	61	64	68	67.9	5.2
Customer plate leftover (kg)	69	51	49	56	54	52	58	55.5	6.2
Customers served per day	512	456	412	423	402	417	489	444.4	39.2
Total food waste (kg)	400	338	269	316	229	344	346	320.3	51.9
Food waste per customer (kg/person)	0.78	0.74	0.65	0.74	0.57	0.82	0.71	0.72	0.077

Fig. 2 shows that the majority of food waste (52%) was generated during food preparation, but it should be noted that the largest portion of food waste generated during food preparation was an unavoidable waste (inedible parts of food), as shown in Fig. 3. The results of the categorization of food waste fractions into avoidable and unavoidable fractions shown in Fig. 3 show that, with the exception of the aforementioned food preparation waste, the majority of the food waste generated in this study was avoidable, because customer plate leftovers, buffet leftovers, and storage waste were made up of 95%, 91% and 89% of avoidable fractions respectively. These results are similar to the results found by Papargyropoulou et al. [14] and Betz et Al. [15] who reported that the majority of unavoidable waste was generated during food preparation.

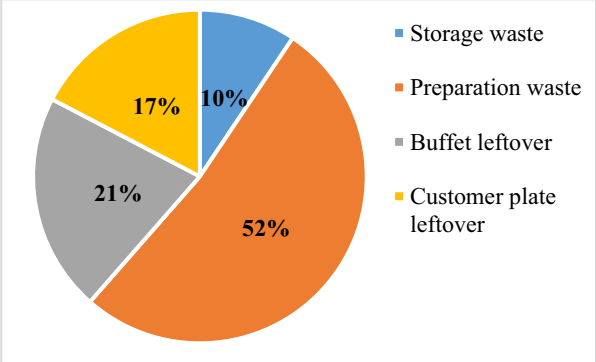

Fig. 2. Food waste percentage (%) per food waste category.

Fig. 4 shows the average daily food waste generated by the food commodity category. Based on Fig. 4, vegetables constituted the majority of food commodities wasted during food preparation (31.2 kg/day) and storage (6.6 kg/day) followed by fruits, with 25.8 kg/day of waste during preparation, and 5.5 kg/day of waste during storage. Food preparation generated a high amount of vegetable and fruit waste because a considerable portion of that waste was made up of inedible parts, such as peels, shells, skin, and seeds. As for food storage, vegetable and fruit waste were mostly constituted of salads that should not be stored for more than 3 days because they spoil quickly, and due to the relatively high amount of salads stored, some of them were not used before they had expired, thus they had to be thrown away.

As for buffet and customer plate leftovers, cereals constituted the majority of food commodities wasted, with 15 kg/day and 10.2 kg/day for buffet and customer plate leftovers respectively, followed by poultry, with 11 kg/day and 9.5 kg/day for buffet and customer plate leftovers respectively. Buffet and customer plate leftovers were mostly made up of cereals and poultry because the bread and rice served to the customers were not consumed entirely, while poultry waste was mostly made up of inedible fractions such as bones and skin.

Overall, the most wasted food commodities were vegetables (50.8 kg/day in total), fruits (47.1 kg/day in total), sauces (39.9 kg/day in total), and cereals (38.4 kg/day in total). Meanwhile, the least wasted food commodities were eggs (10.2 kg/day in total) and dairy products (11.7 kg/day in total). In a study by Thamagasorn and Pharino [26] conducted on a flight catering business, vegetables were also found to be the most wasted food commodities. This indicates that the vegetable waste generated during the preparation of vegetables, which is mostly made up of unavoidable fractions, should be given higher consideration for waste reduction.

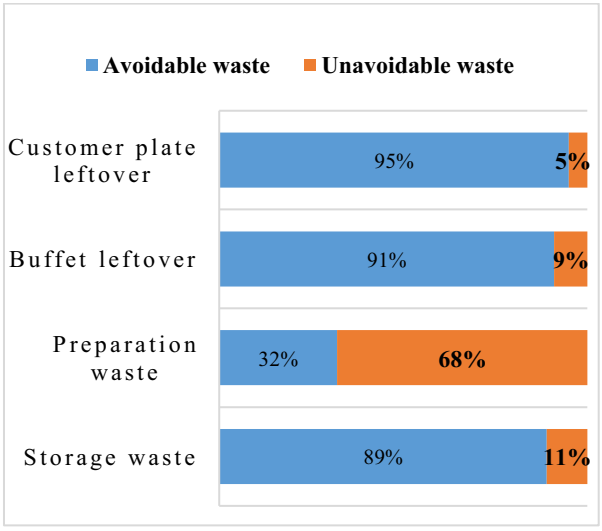

Fig. 3. Percentages of the avoidable and unavoidable fractions of food waste.

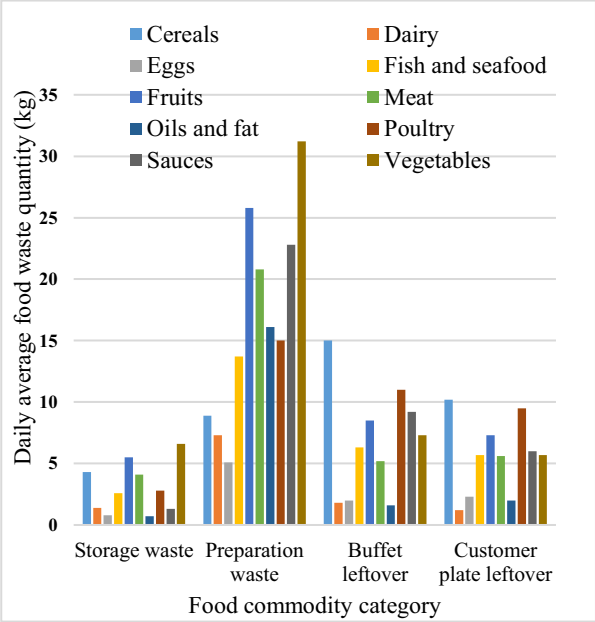

Fig. 4. Average daily food waste (kg) per food commodity category.

The results of the Eco-efficiency analysis of food commodities are shown in Fig. 5. At the top right quarter of the graph, fish, seafood, meat, and poultry are located. This means that fish, seafood, meat, and poultry have a low Eco-efficiency due to their high cost and the high percentage of waste that they generated. Dairy, oils, and fat have a relatively high cost, but they generated a lower amount of waste, thus they have a medium Eco-efficiency. Cereals, sauces, fruits, and vegetables are located at the bottom right quarter of the graph because they are relatively less costly, but they generated a relatively higher amount of waste, thus they have a medium Eco-efficiency. Eggs have a relatively low cost, and they generated a low amount of waste, therefore, they are located at the bottom left quarter of the graph, as a result, they have a high Eco-efficiency.
Interestingly, Thamagasorn and Pharino [26] and Papargyropoulou et al. [14] also found that fish and seafood were the food commodities with the lowest Eco-efficiency. These results were used by the management department of the hotel to better guide the hotel's food waste prevention strategy by prioritizing low Eco-efficiency food (high cost – high waste), followed by medium Eco-efficiency food (high cost – low waste or low cost – high waste), and lastly high Eco-efficiency food (low cost – low waste).

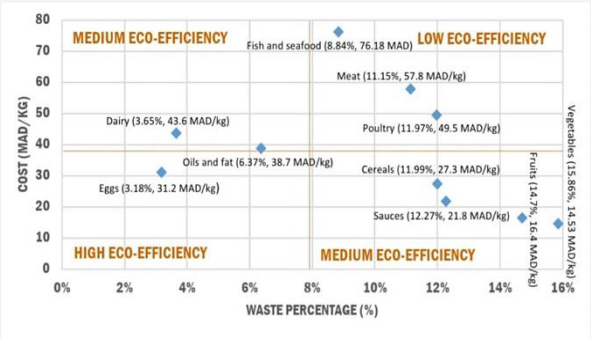

Fig. 5. Eco-efficiency of food commodities.

3.2 Assessment of the methods and conditions of storing and handling food

The analyses of the registers of daily food reception, as well as the assessment of food storage and handling conditions, revealed a few anomalies shown in Table 5. Concerning food reception, the temperatures of some products weren't properly monitored, and since any increase in temperature promotes and accelerates microbial growth, thus reducing the product's shelf life [27], it's necessary to monitor the temperatures of all the products that need to be kept cold to ensure that only products of a satisfactory quality are accepted.

Concerning the storage at room temperature, first, the area where the food is stored lacked an air extractor and a hygrometer, which are both necessary to decrease the humidity in the area and to make sure it does not reach the level that allows for mold growth [28]. Furthermore, the presence of cardboard packaging as well as food stored near the floor may contribute to food wastage through pests and humidity.

Finally, some foodstuffs were not arranged according to the FIFO policy, thus causing some of the food stored to spoil [29] because it was not used within its shelf life. As for the storage in positive temperature and negative temperature cold rooms, first, some foodstuffs weren't properly protected with cellophane paper which can facilitate their contamination by airborne microbes [30] and during hygiene inspections, foodstuffs found in this condition are always discarded. Furthermore, raw eggs were not separated enough from some processed products, which could facilitate cross-contamination [31]. Finally, some thermometers weren't functioning properly, making it impossible to monitor the temperatures of some cold rooms.

A few anomalies were also detected for food handling. First of all, the cleaning and disinfection of fruits and vegetables weren't monitored properly because there weren't any test strips to verify the effectiveness of the vegetable disinfection product.

In addition, during food preparation, the kitchen staff noticed that some fruits and vegetables started to spoil, and they reported that this problem occurs regularly. Upon investigation, we found that the main cause for this problem concerns the storage conditions of fruits and vegetables because the storage temperature wasn't lowered enough to slow the ripening process associated with ethylene release, since this gas is responsible for ripening [32], and a low temperature decreases its release. Indeed, several authors in the literature have discussed the role that ethylene plays in food spoilage during food storage [33-35], making it an important parameter to monitor and control during food storage.

Finally, some utensils and cutting boards used were made of wood, which is not ideal, since wooden cutting boards for example facilitate microbial growth [22] due to the porosities that they contain.

Table 5. Anomalies detected for the various procedures.

Procedure	Anomaly
Food reception	The temperatures of some products weren't properly monitored
Storage at room temperature	Absence of an air extractor and a hygrometer to control and monitor the humidity in the area
	Some cardboard packaging was present in the area
	Some foodstuffs were stored near the floor
	Some foodstuffs weren't stored according to the FIFO policy
Storage in positive temperature and negative temperature cold rooms	Some foodstuffs weren't adequately protected
	Some thermometers weren't functioning properly
	Raw eggs were not separated enough from some processed products
Cleaning and disinfection of fruits and vegetables	Lack of availability of test strips to verify the effectiveness of the vegetable disinfection product
Handling of fruits and vegetables	Some fruits and vegetables started to spoil, therefore, all of them had to be thrown away
Use of kitchenware	Some utensils and cutting boards used were made of wood material

3.3 The action plan established based on the results of the various assessments

The anomalies detected during the food waste audit and the assessment of the methods and conditions of food storage and handling were incorporated into an action plan (Table 6) addressing the measures to be taken to reduce food waste in the hotel restaurant concerned by this case study. The action plan prioritized the reduction of vegetable and fruit waste because these food commodities were found to be wasted the most during the food waste audit. As such, the decrease in the temperatures of cold rooms where fruits and vegetables are stored, as well as the adjustment and calibration of all thermometers used in cold rooms, were the corrective actions that were decided.

Table 6. An action plan established based on the results of the various assessments.

Anomalies	Corrective actions	Agent(s) responsible for taking corrective actions	Agent(s) responsible for monitoring corrective actions	Time limit
The temperatures of some products weren't properly monitored	Recording of the temperatures of all products received on the food reception register	Receiving clerk	Quality manager	July 2021
Absence of an air extractor and a hygrometer to control and monitor the humidity in the dry storage area	Installation of an air extractor and a hygrometer in the area where the food that should be kept at room temperature is stored	Technical engineer	Quality manager	August 2021
Some cardboard packaging was present in the dry storage area	Removal of cardboard packaging from the products stored	Storage clerk	Quality manager	August 2021
Some foodstuffs were stored near the floor	Storage of all foodstuffs on shelves away from the floor by at least 15 cm	Storage clerk	Quality manager	July 2021
Some foodstuffs weren't stored according to the FIFO policy	Storage of all foodstuffs according to the FIFO policy	Storage clerk	Quality manager	July 2021
Some foodstuffs weren't adequately protected	Wrapping (in cellophane) and labeling of all foodstuffs stored in cold rooms	Kitchen staff	Kitchen chef/Quality manager	July 2021
Some thermometers weren't functioning properly	Adjustment and calibration of all thermometers used in cold rooms	Technical engineer	Quality manager	July 2021
Raw eggs were not separated enough from some processed products	Separation of raw eggs from processed products	Kitchen staff	Kitchen chef/Quality manager	July 2021
Lack of availability of test strips to verify the effectiveness of the vegetable disinfection product	Purchase of test strips	Supply manager	Quality manager	August 2021
Some fruits and vegetables started to spoil, therefore, all of them had to be thrown away	Decrease of the temperatures of cold rooms where fruits and vegetables are stored	Technical engineer	Quality manager	July 2021
Some utensils and cutting boards used were made of wood material	Replacement of all wooden utensils and cutting boards with polyethylene and stainless steel	Supply manager	Quality manager	August 2021
Low and medium Eco-efficiency food	Reduction of the quantities of low and medium Eco-efficiency foods purchased	Supply manager	Quality manager	June 2022
Buffet and customer plate leftovers	Staff training in menu portioning	Certified trainer	Kitchen chef	June 2022
Unsorted waste	Waste sorting in 4 waste bins: a yellow one for plastic, cardboard and metal packaging; a red one for food waste; a green one for glass packaging; and a blue one for papers.	Kitchen staff/stewards	Quality manager	July 2021

The action plan also focused on low and medium Eco-efficiency food, especially the former, consisting of fish, seafood, meat, and poultry. As such, the reduction of the quantities of low and medium Eco-efficiency foods

purchased was the corrective action that was decided. To decrease the amount of food wasted during service (buffet and a la carte), staff training in menu portioning, i.e., the control of portion and plate sizes, was considered as a corrective action. It should be noted that while this specific action has the potential to decrease food waste associated with internal factors that can be controlled by the kitchen and restaurant staff, it can't decrease food waste associated with external factors (i.e. customer behavior) because they remain outside of the hotel's control.

3.4. Determination of the percentages of food consumed and wasted before and after the execution of the action plan

During June 2021, i.e., before the execution of the action plan, the quantity of food utilized by the hotel during the food waste audit week was 6,398.7 kg. The average weekly quantity of food wasted week was 2,239.3 kg. The results of the determination of the percentages of food consumed and wasted before the execution of the action plan discussed in the previous section (section 3.3) are presented in Fig. 6. Since 2,239.3 kg was wasted out of 6,398.7 kg, then 4,159.4 kg was consumed. Therefore, the percentage of consumed food was 65%, and the percentage of wasted food was 35%.

During July 2022, i.e., approximately 4 months after the hotel began the execution of the action plan (the hotel closes in mid September and opens in mid to late May, and the execution of the action plan started in July 2021, the food waste reduction analysis took place in July 2022, i.e. 4 months after the start of the execution of the action plan), the quantity of food utilized by the hotel during the food waste audit week was 5,684 kg. The average weekly quantity of food wasted was 1,137.2 kg. The results of the determination of the percentages of food consumed and wasted after the execution of the action plan discussed in the previous section (section 3.3) are presented in Fig. 7. Since 1,137.2 kg was wasted out of 5,684 kg, then 4,546.8 kg was consumed. Therefore, the percentage of consumed food was 80%, and the percentage of wasted food was 20%. Thus, after the execution of the action plan, the percentage of food wasted went from 35% to 20%.

The reason behind this decrease in food waste is the implementation of the corrective measures defined in the action plan, particularly in regard to staff training in menu portioning; the improvement of storage conditions of food, particularly in regard to the application of the FIFO policy and the control of food temperatures, including the storage temperatures of vegetables and fruits; and the reduction of the quantities of low and medium Eco-efficiency foods purchased. Effective communication between the different departments of the hotel proved necessary in terms of ensuring that all the parties involved in the food prevention strategy were performing their tasks in accordance with the objectives defined.

In a study reviewing the results of food waste reduction in 13 establishments belonging to the foodservice sector in Switzerland and Germany [36], it was found that it was possible to reduce food waste within a few weeks or months by 38%. Since the food waste percentage went from 35% to 20% (a 15% decrease) in our case, a further decrease in food waste is possible.

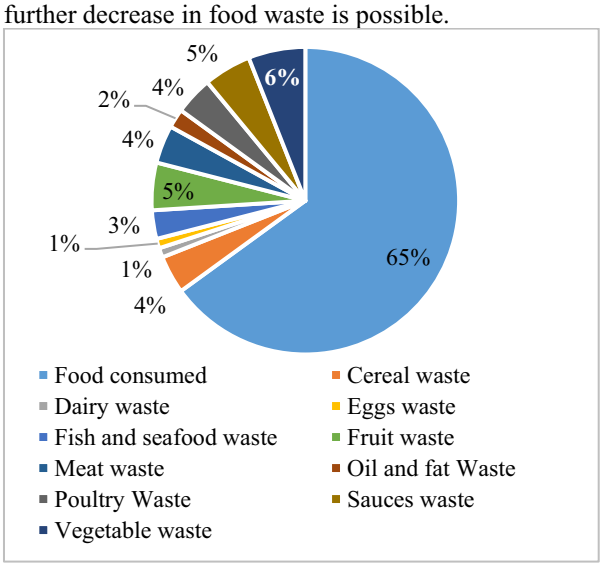

Fig. 6. Food consumed and wasted (%) during the food waste audit week in June 2021.

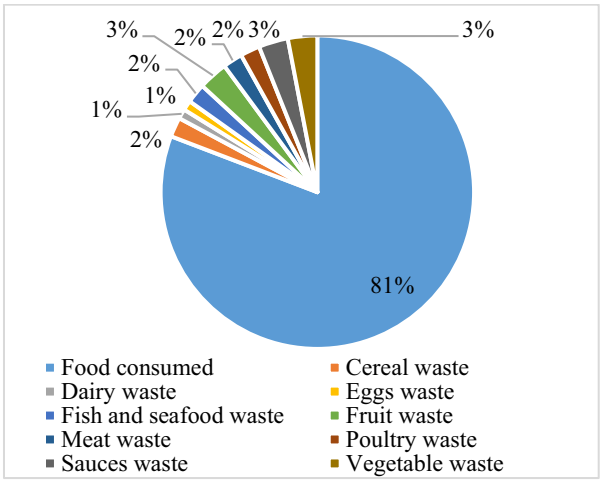

Fig. 7. Food consumed and wasted (%) during the food waste audit week in July 2022.

4 Conclusion

In this work, we contributed to the development of a food waste prevention strategy in a restaurant operating within a hotel in the city of Saidia in Eastern Morocco. Food preparation generated the highest amount of average daily food waste, while storage waste generated the lowest amount. Fruits and vegetables were the most wasted food commodities, and food preparation generated the highest amount of waste. The low Eco-efficiency food commodities were fish, seafood, meat, and poultry. Thus, the action plan established based on the food waste audit and the assessment of the methods and conditions of food storage and handling prioritized decreasing the amount of the most wasted food commodities and low Eco-efficiency food commodities, as well as improving food preparation practices. Food waste went from 35% to 20%, and a further decrease in food waste is possible in our case, as long as the food waste prevention strategy is regularly monitored and

improved. Staff training, as well as effective communication between the different departments of the hotel, proved essential during our study.

The perspectives derived from this work can be summarized as follows:

- First, this work can be used by businesses to develop their food waste prevention strategies. It can also provide an initial framework that can be expanded upon by studies aiming to both understand the reasons behind food waste and decrease food waste.
- Second, the information provided by this study on which food commodity was wasted can be used by studies with similar aims to build a comprehensive database about the most wasted food commodities.
- Third, the Eco-efficiency analysis carried out in this work can help organizations in guiding their efforts in reducing food waste by targeting specific food waste commodities.
- Finally, the economic benefits gained from food waste prevention can be an incentive for organizations towards environmental protection.

5 References

1. F. Donati, A. Tukker, Sustainability, **14** 6057 (2022)
2. S. Lazarova, D. Coyne, M.G. Rodríguez, B. Peteira, A. Ciancio, Diversity, **13** 1–22 (2021)
3. S.M.H. Qadri, Y.H. Sharief, N.D. Beevi, A. Mani, Indian Silk, **43** 11–13 (2004)
4. A.M.D. Ortiz, C.L. Outhwaite, C. Dalin, T. Newbold, One Earth, **4** 88–101 (2021)
5. M. Reavis, J. Ahlen, J. Rudek, K. Naithani, Front Sustain Food Syst, **5** (2022)
6. O. Miseckaite, H. El Bilali, S. Berjan, B Abstr VIII Int Sci Agric Symp **00** 965 (2017)
7. L. Heikkilä, A. Reinikainen, J.M. Katajajuuri, K. Silvennoinen, H. Hartikainen, Waste Manag, **56** 446–453 (2016)
8. J. Parfitt, M. Barthel, S. MacNaughton, Philos Trans R Soc B Biol Sci **365** 3065–3081 (2010)
9. F.H.T.Q. Clementine. O, *Food Waste Index Report* 2021
10. J. Poore, T. Nemecek, Science, **360** 987–992 (2018)
11. B. Grizzetti, U. Pretato, L. Lassaletta, G. Billen, J. Garnier, Environ Sci Policy, **33** 186–195 (2013)
12. C. Beretta, M. Stucki, S. Hellweg, Environ Sci Technol, **51** 11165–11173 (2017).
13. S. Hsu, S. Banskota, W. McCormick, J. Capacci, C. Bustamante, K. Moretti, D. Wiegn, K.D. Martin, J. Clim Chang Heal, **4** 100041 (2021)
14. E. Papargyropoulou, N. Wright, R. Lozano, J. Steinberger, R. Padfield, Z. Ujang, Waste Manag, **49** 326–336 (2016)
15. A. Betz, J. Buchli, C. Göbel, C. Müller, Waste Manag, **35** 218–226 (2015)
16. R. Engström, A. Carlsson-Kanyama, Food Policy, **29** 203–213 (2004)
17. P. Brancoli, F. Makishi, P.G. Lima, K. Rousta, Sustainability, **14** 7014 (2022)
18. I. Alaoui, S. Chbaatou, T. El Khyari, *Joint Order of the Minister of Agriculture, Rural Development and Waters and Forests, the Minister of Maritime Fisheries and the Minister of Health No. 440-01 of 2 hija 1421 (February 26, 2001) relating to the period of validity and the storage conditions*, 2001
19. M.A. Hussain, Foods, **5** 1–2 (2016)
20. K.C. Dannemiller, C.J. Weschler, J. Peccia, Indoor Air, **27** 354–363 (2017)
21. T. Roberts, P. Graham, Virginia Cooperative Extension Food Safety Food Storage Guidelines For Consumers, (2001)
22. A.J. Miller, T. Brown, J.E. Call, J. Food Prot, **59** 854–858 (1996)
23. T.I. Assis, R.F. Gonçalves, J. Environ Manage, **320** 115763 (2022)
24. Y. Wang, Y. Tang, Z. Yuan, Bioresour Technol, **349** 126830 (2022)
25. K. Silvennoinen, L. Heikkilä, J.M. Katajajuuri, A. Reinikainen, Waste Manag, **46** 140–145 (2015)
26. M. Thamagasorn, C. Pharino, J. Clean Prod, **228** 845–855 (2019)
27. B. Zhou, Y. Luo, L. Huang, J.M. Fonseca, H. Yan, J. Huang, Food Control, **133** 108639 (2022)
28. S. Bin, H. Sik, K. Joon, J. Hak, J. Hee, Atmos Environ X, **15** 100182 (2022)
29. A. Akkas, D. Honhon, *Determining Maximum Shipping Age Requirements for Shelf Life and Food Waste Management (UN)* pp 1-38 (2013)
30. E. Zand, G. Brockmann, F. Schottroff, M. Zunabovic-pichler, A. Hartmann, M. Kriegel, H. Jaeger, J. Food Eng, **334** 111157 (2022)
31. H. Keskinoğlu, G. Terzi Gülel, Eurasian J. Vet Sci 24–31 (2022)
32. H. Wei, F. Seidi, T. Zhang, Y. Jin, H. Xiao, Food Chem, **337** 127750 (2021)
33. F. van Holsteijn, R. Kemna, Resour Conserv Recycl, **128** 25–31 (2018)
34. N. Keller, M.N. Ducamp, D. Robert, V. Keller, Chem Rev, **113** 5029–5070 (2013)
35. R. Couture, M.I. Cantwell, D. Ke, M.E. Saltveit, HortScience, **28** 723–725 (1993)
36. C. Beretta, S. Hellweg, Resour Conserv Recycl, **147** 169–178 (2019)