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Quantitative and qualitative assessment of food waste in rural markets in Morocco

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ABSTRACT

Background: Food waste, a significant issue in sustainable food systems, occurs at various stages of the food supply chain, from production to consumption. However, there is limited data assessing the quantity and nutritional value of food waste at the retail level, especially in rural markets (*Souks*). **Aims:** This research aimed to characterize and quantify the nutritional value of food waste in rural retail markets of El Jadida and Sidi Bennour in Morocco. **Material and Methods:** A quantitative approach was employed, combining observational diagnosis of food waste types and a survey of sellers to collect information, through a questionnaire, on purchased and remaining quantities, as well as the nature and disposal of food waste. The nutritional value of wasted food was estimated using the Ciqual food composition table and the bilnut calculation program. **Results:** The estimated quantity of unsold food in the studied retail markets was 1135.36 tons/year, equivalent to 0.85 kg/inhabitant/year for the region's population. Vegetables accounted for the largest proportion of unsold food (45.7%), followed by fruits (27.4%), and meat and offal (10.8%). The estimated quantity of food waste was 677.3 tons/year or 0.5 kg/inhabitant/year. The daily nutritional value of wasted food in the studied *Souks* was estimated to be 118.173 kcal, 7.616 g of carbohydrates, 6.026 g of proteins and 6.386 g of total fats, 1.579 g of dietary fiber, 334 mg of vitamin A, 1.6 mg of vitamin D, 945.9 mg of iron, 21.712 mg of calcium, 1.903 mg of potassium, and 4.56 mg of iodine. These nutrient contents could potentially contribute to the daily needs of a significant portion of the population, particularly for iron, as the estimated daily loss of 945.9 mg/day could meet the recommended daily intake of 59 adult women or 236 children under five years old. **Conclusion:** This study provides a novel comprehensive assessment of the nutritional value lost due to food waste in rural retail markets in El Jadida-Sidi Bennour. The findings reveal the need for improved supply chain management and demand forecasting to reduce food waste. Strengthening efforts to redistribute and reuse wasted food can contribute to addressing nutritional deficiencies and food insecurity among vulnerable rural populations.

Keywords: Food waste, retail trade, valorization, nutritional loss, rural markets.

ARTICLE INFORMATION

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1 Introduction

According to the Food and Agriculture Organization (FAO), approximately one-third of food intended for human consumption is lost or wasted annually throughout the global food supply chain at local, national, regional and global levels (FAOSTAT, 2014). Food is wasted or lost at

different stages of production, after harvesting, processing, distribution and consumption, i.e., at all stages and processes of the supply chain from farm to table. This food loss and waste not only has environmental implications but also contributes to food insecurity for millions of people worldwide (Vootla et al., 2018). The latest FAO report on food security indicates that 29.6% of the global population,



or 2.4 billion people, did not have constant access to food, of which 900 million experiencing severe food insecurity. This report indicates that hunger has increased and remains at a level well above that recorded before the COVID-19 pandemic. In 2022, 735 million people suffered from hunger, mostly in the African region (FAO, 2021). The situation is all the more worrying if we consider forecasts of global population growth which is expected to reach more than nine billion inhabitants by 2050 (Nations Unies, 2017). Morocco also has 6.3% of its total population, or 2.3 million Moroccans, suffering from undernourishment in 2020-2022 (FAO, 2021). According to the United Nations report, data on the nutritional situation in 2022 shows that in Morocco, 0.1 million children suffered from wasting and 12.8% from stunted growth. Furthermore, several micronutrient deficiencies were recorded in 2019 with a prevalence of iron deficiency anemia in 29.9% of women of childbearing age (Nations Unies, 2017) and in 31.6% of children under 5 years old, a Vitamin A deficiency was also prevalent in 40.90% of these children and 63% of children aged 6 to 12 years had iodine deficiency, of which 22% had goiter (SNN, 2023). Morocco also faces significant food waste challenges, with an estimated 3,319,524 tons of food wasted annually, equivalent to approximately 91 kilograms of food per capita per year (FAO, 2021). Iron deficiency alone results in a shortfall of approximately two billion MAD, in addition to the 6.28 million USD investment for the strategy of fortifying flour with iron and folic acid in Morocco (Gain, 2014). Reducing food loss and waste is crucial for addressing hunger, malnutrition, and food security. It is also essential for improving the efficiency and sustainability of food systems, from production to consumption (UNEP, 2024). Furthermore, it could significantly lower food costs, enhance food security, and positively impact the environment by reducing greenhouse gas emissions and preserving natural resources.

Given the limited data on food loss and waste, particularly at the retail level in Morocco, this study aimed to quantify and characterize food waste in weekly rural markets (*Souks*) of El Jadida-Sidi Bennour. By assessing the types and quantities of food wasted, this research seeks to shed light on the extent of food and nutritional losses within this specific retail context.

2 Material and Methods

2.1 Study concept

This study was carried out between February 2022 to March 2023 in five rural markets (*Souks*) located in the provinces of El Jadida and Sidi Bennour. Among the 33 *Souks* in these two provinces, the *Souks* of Tlat Sidi Bennour, Khmiss Zemamra, Had Ouled Frej, Tnin Lgharbia and Sebt Douib, were

selected based on their vocation, size, location and income (EESC, 2020).

The research employed a quantitative approach, consisting of two phases. The first phase involved an observational diagnosis to identify the type of wasted food and food waste. The second phase involved a survey of *Souk* sellers, utilizing a questionnaire to collect data on daily purchases, remaining quantities, and the nature and disposal of food waste.

To account for seasonal variations in purchasing, sales, and food waste patterns, the survey was conducted over a full year, from February 2022 to March 2023, to consider seasonal variations. This comprehensive approach ensured a representative overview of food waste practices in the selected *Souks*.

2.2 Data source

2.2.1 Development of the questionnaire

The questionnaire was developed based on existing literature on food waste assessment and expert consultation. The instrument, filled face-to-face, was designed to capture information on various aspects of food waste, including the quantity purchased, unsold quantities, the fate of leftovers, and the types of food wasted. To ensure content validity and reliability, the questionnaire was also pre-tested with a sample of retailers to assess its clarity and relevance. Finally, feedback from retailers on the relevance of the questions reinforces the face validity of the questionnaire.

As this study is a pioneering effort in this domain, a comprehensive approach was adopted to estimate the overall food waste. Therefore, no specific food types were targeted, and all food items sold in the surveyed markets were considered.

2.2.2 Permissions and consent

While formal ethical approval from an Institutional Review Board (IRB) was not required for this study, prior permission was obtained from local authorities. Verbal informed consent was obtained from participating traders, who were informed about the study objectives and their right to withdraw at any time.

A total of 600 traders were surveyed to collect quantitative data on foods intended for sale including vegetables, fruits, meat and offal, fish and seafood, bakery products and aromatic plants. A sample of 100 retailers was selected from each food category. Data collected involved face-to-face interviews using a structured questionnaire which captured information on the quantities of food purchased, unsold quantities, and the nature and disposal of food waste. The survey was conducted in dialectal Arabic and typically took 45 minutes per respondent.

The “Bilnut” program, supplemented by the “Ciqal” database, was used to determine the nutritional composition of wasted food items and estimate nutrient losses content and the extent of nutrients lost at the retail level in weekly rural *Souks*. Inedible portions of foods were excluded from the analysis. Additional data on recommended dietary intakes and population estimates for the El Jadida and Sidi Bennour regions were sourced from the High Commission for Planning (HCP) (HCP, 2014).

2.3 Calculations of food losses and waste

To determine the extent of food loss and waste, the quantity of different unsold food items within each category was quantified for each of the five studied *Souks*. Also, for each food category the quantity of each food variety within the category is estimated as well as the proportion (in %) corresponding to its fate and finally the food waste per capita is evaluated. The quantity of food waste per *Souk* Day of each food category including 123 wasted food varieties is determined in the five rural markets studied. The average daily food waste per *Souk* was multiplied by the total number of *Souks* in the region (33) to estimate the total weekly food waste at the regional level. Annual food waste was then calculated based on a 52-week year.

The nutritional value of wasted food was estimated using the “Bilnut” program from the composition of the 123 varieties of food identified in food waste per *Souk* Day. The total nutritional loss resulting from the waste of all 123 foodstuffs in the weekly *souks* studied is estimated by calculating the sum of the quantities of a nutrient present in each food variety identified in the waste per *Souk* Day. The contribution in energy or nutrients to be recovered from food waste is estimated from this nutritional value divided by the recommended daily intake for adult women or by the recommended daily allowance (RDA) for children under 5 years old. The recommended dietary intake (RDI) values were based on the Moroccan nutrition guide (Ministry of Health, 2016). The term “adult” applies to individuals aged 19 to 30 years old. The recommendations for this group are equivalent to the recommendations for the 31 to 50 age group. Regarding Energy, 2000 kcal/day has been employed as the RDA for adult women, although actual needs depend on height, weight and physical activity.

2.4 Statistical analysis

Data on food quantities were categorized by food categories (vegetables, fruits, meats and offal, fish and seafood, bakery products and aromatic plants) and entered into Excel spreadsheets. Continuous variables are presented as means \pm standard deviation, while categorical variables are reported as frequencies and percentages. The student “*t*” test was used to compare means of continuous variables, and the Chi-square

test or Fisher’s exact test was used to assess the independent distribution of categorical variables. All data were analyzed using SPSS version 25 (Inc., Chicago, IL, USA). Statistical significance was set at a *p*-value < 0.05.

3 Results

3.1 Quantities of unsold food by category

To facilitate the analysis of food waste patterns and identify the most affected food categories, the data were categorized into six groups: bakery products, meat and offal, fruits, vegetables, fish and seafood, aromatic plants. This approach facilitated the assessment of nutrient losses and allowed more effective targeting of waste reduction efforts.

Table 1 presents the proportion of unsold food within each category. Vegetables and fruits contributed the largest proportion of unsold food, accounting for over 70% of the total. Meat and offal, bakery products, fish and seafood, and aromatic plants accounted for 10.87%, 6.67%, 5.77%, and 3.56%, respectively.

Table 1. Percentage of food not sold per food category per *Souk* Day

Categories	Quantity sold (kg)	Quantity unsold (kg)	Foodstuffs unsold (%)
Bakery Product	5161.3	291.6	6.67
Meat and Offal	6326.8	475.1	10.87
Fruits	13095.4	1196.5	27.39
Vegetables	22135.8	1995.6	45.69
Fish and seafood	1562.2	252	5.77
Aromatic plants	218.2	155.8	3.56
Total	48499.9	4366.8	99.95

Table 2 provides a detailed breakdown of the 123 food items identified within each food category. Vegetables exhibited the highest diversity with 36 items, while the other five categories ranged from 14 and 21 foods.

3.2 Destination of unsold food

Table 3 presents the average weight and percentage of unsold food destined for various purposes. Approximately 73% of all unsold food was either discarded or utilized as animal feed. A significant portion (40%) was directly disposed of as waste, while 26% was distributed to vulnerable individuals or sold at reduced prices in the *Souk*.

Table 2. Number and quantity of food variety wasted by each foodstuff category per *Souk* day

Foodstuff categories	Food varieties	Number of foods (n)	Unsold quantity (kg)	Unsold (%)
Vegetables	Artichoke (raw), Asparagus (green, raw), Eggplant (raw), Beetroot, (raw), Broccoli (raw), Cardon, Carrot (raw), Celeriac (raw), White cabbage (raw), Brussels sprouts (raw), Red cabbage (raw), Cauliflower (raw), Kohlrabi (raw), Lime or Lime (pulp, raw), Cucumber (pulp and skin, raw), Squash (raw), Zucchini (pulp and skin, raw), Fennel (raw), fresh bean, Green beans (raw), Lettuce (raw), Turnip (raw), Onion (raw), Peas (raw), Chili pepper (raw), Leek (raw), Yellow pepper (raw), Red pepper (raw), Green pepper (raw), potato, Yam, Black radish (raw), Red radish (raw) Cherry tomato, round tomato (raw), Jerusalem artichoke	36	1995.6	45.7
Fruits	Apricot (raw), Avocado (pulp, raw), Banana (pulp, raw), Cherry (raw), Prickly pear (pulp and seeds, raw), Fig (raw), Strawberry (raw), Raspberry (raw), Pomegranate (pulp and seeds, raw), Kiwi (pulp and seeds, raw), Mango (pulp, raw), Cantaloupe melon (pulp, raw), Orange (pulp, raw), Papaya (pulp, raw), Watermelon (pulp, raw), Peach (pulp and skin, raw), Pear (pulp and skin, raw), Apple (pulp and skin, raw), Black grape (raw), Yellow grape (raw)	20	1196.5	27.4
Fish and seafood	Common anchovy (raw), Eel (raw), Squid (raw), Crab (raw), Shrimp (raw), Shallot (raw), Langoustine (raw), Mackerel, Whiting (raw), Hake (raw), Mussels (raw), Mullet (raw), Porgy, Ray (raw), Shark (raw), Sardine (raw), Salmon (raw), Sole (raw), Red tuna (raw), Sea trout (raw), Offal, Ox legs and head	20	252	5.8
Meat and offal	Liver, Sheep head and legs, Sausages (raw), Chicken nuggets, Chicken, Beef, Goat meat, Turkey meat, Mutton, Rabbit/hare meat	12	475.1	10.9
Aromatic plants	Garlic (raw), Fresh basilic, Absinthe, Chive, Celery, Coriander, Wild mint, Laurel, Lavender, Lemon verbena, Rose geranium, Fresh mint, Oregano (dried), Rum, Rosemary, Rosemary (fresh), Rocket (Arugula salad), Salami (German tomato), Sage, Parsley, Thyme, fresh	21	155.8	3.5
Bakery and Cereal products	Moroccan pancakes (<i>Beghrir</i> , <i>Harcha</i>), Donuts, Corn flour, Moroccan pancakes with vegetable oil (<i>M'semen</i>), Bran bread, Whole wheat bread, Barley bread, White bread, Corn bread, Sliced bread, whole wheat, Panini bread, Baguette bread, Bran.	14	291.6	6.7
Total		123	4366.8	100

Table 4 presents the total average quantity of food categorized by foodstuff and destinations. Food items given away at reduced prices or for free, intended for human consumption, were distinguished from those discarded as waste or used as animal feed. According to the categories of wasted food, vegetables constituted the largest proportion of food waste (42.97%) followed by fruits (29.79%), Meats and offal (14.34%), bakery and cereal products (5.19%), fish and seafood (4.16%), and aromatic plants (3.51%).

3.3 Nutrient content of food waste

Table 5 presents the nutritional value of the 123 food items identified in the food waste from the studied *Souks*. On average, the daily nutrient losses per *Souk* included 118.173 kcal, 7.616g of carbohydrates, 6.026g of protein, 6.386g of total fat, 1.579g of dietary fiber, 334mg of vitamin A, 1.6mg of vitamin D, 945 mg of iron, 21 712 mg of calcium and 1903 mg of potassium, and 4.56 mg of iodine.

Table 3. Distribution of food waste according to their use or destination

Destination of food waste	Mean ± SD	Percentage (%)
Animal feed	23.82 ± 4.92	33.55
Thrown away	28.65 ± 2.82	40.36
Reduced price or for free	18.51 ± 1.49	26.07
Total	70.98 ± 3.07	99.98

SD: Standard deviation

3.4 Nutrient contents in wasted food compared to the RDA

Table 6 presents the estimated quantities of nutrients lost and their potential contribution to dietary needs. The mean content of nutritional value to be recovered in food waste from the different rural retail markets (per souk day) studied and its equivalent in RDA for adult women and children under five years old is calculated by considering that the

Table 4. Average quantity (kg) and percentage of food categories by destination

Foodstuff Categories	Thrown in the "trash"	Reduced price or for free	Total of unsold food
		Quantity in kg (%)	
Bakery and cereal products	135.46 (5.2)	156.14 (8.86)	291.6 (6.67)
Meats and offal	373.8 (14.34)	101.3(5.75)	475.1 (10.87)
Fruits	776.5 (29.79)	420(23.85)	1196.5 (27.39)
Vegetables	1120 (42.97)	875.6(49.73)	1995.6 (45.69)
Fish and seafood	108.53 (4.16)	143.47(8.14)	252 (5.77)
Aromatic plants	91.61 (3.51)	64.19(3.64)	155.8 (3.56)
Total	2605.9 (100)	1760.7(100)	4366.6 (99.95)

proportions of nutritional value in the recovered foods are comparable to those lost in food wasted by all rural markets included in the study.

Table 5. Amounts of nutrients determined in food waste at the retail level

Waste food composition	Content
Energy (kcal)	118173.6
Carbohydrates (g)	7616.81
Protein (g)	6026.1
Total fat (g)	6386.95
Saturated fat (g)	2481.32
Monounsaturated fat (g)	2280.84
Polyunsaturated fat (g)	718.66
Cholesterol (mg)	30981.09
Dietary fiber (g)	1579.9
Minerals	
Calcium (mg)	21712.55
Iron (mg) ^a	945.9
Magnesium (mg)	18462.16
Phosphorus (mg)	83569.74
Potassium (mg)	209604.48
Sodium (mg)	71499.57
Zinc (mg)	1033.87
Iodine (mg) ^a	4.56
Vitamins	
Vitamin A (mg) ^{a,b}	334.09
Thiamine (mg)	101.47
Riboflavin (mg)	1633.55
Niacin (mg)	416.24
Vitamin B ₆ (mg)	2694.96
Folate (mg)	26.1
Vitamin B ₁₂ (mg)	13.49
Vitamin C (mg)	7661.08
Vitamin D (mg)	1.6
Vitamin E (mg)	4734.48
Vitamin K (mg)	18.02

^a Nutrients for which the food intake of the population is deficient, and which have been the subject of enrichment of certain foods as part of the food enrichment program set up in Morocco by the Ministry of Health to fight against these deficiencies, ^b activity equivalents of retinol

Table 6 presents the estimated contribution of the lost nutrients in food waste to the RDI for adult women and children under five years old. For instance, the estimated daily loss of iron in El Jadida -Sidi Bennour region was 945.9 mg (as shown in Table 5), which is equivalent to the RDI for 59 adult women or 236 children under five years old.

4 Discussion

This study contributes to the global efforts to reduce food waste and achieve the Sustainable Development Goal 12.3 of the United Nations (UN) aiming to reduce food waste by 50%, from distribution to consumption by 2030 (Nations Unies, 2017). The study aimed to assess the quantity and nutrient content of food waste at the retail level in rural markets or *Souks*. The results indicate that a significant amount of food, rich in essential nutrients, is wasted in these *Souks*. Recovering and utilizing this wasted food could help address nutritional deficiencies and improve food security, particularly for vulnerable populations. In fact, the nutritional value of recovered foods, as assessed in this study, would contribute to the equivalent of the RDA in several micronutrients including iron, calcium, dietary fiber and vitamin E.

4.1 Quantities of unsold food by category

This study quantified food waste in previously unexplored retail settings: rural markets (*Souks*), in the agricultural region of El Jadida-Sidi Bennour. The survey data revealed that a large quantity of food estimated at 43 tonnes, was unsold in these markets, representing approximately half of the total purchased quantity (Table 1). This substantial food loss can be attributed to various factors.

4.2 Quantities of unsold food by category

This study quantified food waste in a previously unknown location among points of sale, namely rural markets locally called souks, in the agricultural region of El Jadida-Sidi Bennour. Data from the survey carried out as part of this study report that a large quantity of foodstuffs estimated at 43

tonnes of food was unsold in the souk, representing approximately half of the quantity purchased (Table 1) and which is lost. The various reasons for this loss include deterioration of these foods' quality, due to insufficient and poor quality of transportation, refrigeration and poor storage infrastructure in rural markets, leading to considerable reduction in the quality of the food products in the markets compared to that at farm level. Further studies reported that these constraints are considered among the main reasons for food waste in developing countries (FAO, 2012).

chain, from primary production to the final consumption level" (FAO, 2021). While diverting food waste into animal feed is a common practice in some regions, such as New Zealand, it is subject to strict regulations in several European Union countries and the United Kingdom due to concerns over potential contamination. In these regions, food waste intended for animal feed must be certified safe or treated in temperature to comply with regulatory standards (Saleem et al., 2017).

In the present study, over 33% of unsold food was utilized as animal feed (Table 3). This quantity diverted to animal feed,

Table 6. Estimated nutrient losses at retail level per souk day in terms of RDA of adult women and under 5 children

Nutrients	RDA for adult women	Equivalent in terms of RDA for adult women	RDA for children under 5 years old	Equivalent in terms of RDA for <5 children
Energy (kcal)	2 000	59.08	1200	98.5
Carbohydrates (g)	130	58.59	60	126.9
Protein (g)	46	131	15	401.74
Dietary Fiber (g)	25	63.19	10	—
Calcium (mg)	900	24.12	450	31
Iron (mg) ^a	16	59.11	4	236
Magnesium (mg)	250	59.55	210	87.9
Iodine (mg) ^a	0.15	30.4	0.09	0.05
Vitamin A (mg) ^a	0.7	0.47	0.3	1.11
Vitamin C (mg)	110	102.14	30	102.14
Vitamin D (mg) ^a	0.015	0.10	0.015	0.3
Vitamin E (mg) ^a	9	315.6	7	946.9

^a Nutrients for which the population food intake is deficient, these nutrients are added to certain foods as part of the food fortification program set up by the Moroccan Ministry of Health to fight against these deficiencies.

Indeed, the exposure of perishable goods to various handling stresses in the market environment can lead to significant quality deterioration. Fruits and vegetables, in particular, are susceptible to damage, rendering them unsaleable at the end of the day in *Souks*. To moderate losses, retailers often segregate damaged products and display them at reduced prices before ultimately discarding them. Vegetables (45.7%) and fruits (27.4%) constitute the largest proportion of unsold food, followed by meat and offal (10.8%). The lack of adequate refrigeration infrastructure in these rural markets, especially for perishable goods such as meat, contributes to accelerated spoilage and increased food waste. The challenge of accurately forecasting market demand, as identified by Sternmarck et al. (2011), is another significant factor contributing to food waste in these markets.

4.3 Food diverted to animal feed

According to the FAO, food waste is defined as "safe and nutritious food produced for human consumption that is discarded or diverted to non-food uses throughout the supply

estimated in the mass distribution sector as 0.04 kg/inhabitant/year, is lower than the quantities of food waste estimated at around 0.5 kg /inhabitant /year that are diverted to feed animals in the United Kingdom (Parfitt et al., 2016). This is considerably lower than the estimated 6 kg/capita/year in the New Zealand retail sector (Goodman-smith et al., 2020).

4.4 Food diverted to food donation

Approximately 7% of the unsold food in the studied rural markets was donated to needy individuals, beggars in the *Souks* or distributed within the traders' households (Table 3). This percentage is comparable to the proportion of food donated by retailers in Austria (Lebersorger & schneider, 2014). This proportion of food donations observed in a developed country like Austria can nevertheless be considered low. Additionally, although this low proportion can be attributed to retail policy, some retailers not allowing food donations to charity (Lebersorger & Schneider, 2014). In Morocco, ethical considerations may have limited the direct disposal of food, leading to a higher proportion of food being

diverted to animal feed or distributed to those in need, which is consistent with Sustainable Development Goals (SDG), aiming to end poverty in all its forms.

4.5 Diversion of foodstuffs

The study found that approximately 60% of unsold food in the rural markets was ultimately disposed of as waste (Table 3). This proportion is lower than 72% in the United States (US) retail sector, as reported by the Alliance to Reduce Food Waste (FWRA, 2016) and lower than the 77% of food thrown away by New Zealand retailers (Goodman-smith et al., 2020). However, although further improvements are still needed since it is estimated that 40% of food ends up in the trash, the results of the present study, showing lower quantities of food thrown away in Moroccan markets, suggest that *Souk* retailers or rural markets studied were making efforts to directly divert food waste from being thrown into the trash. Ensuring appropriate use of food waste also requires formal practices and commitments. Additionally, establishing an organizational culture is an important process for integrating a focus on food waste utilization into routine waste management practices at retailers. For UK retailers, recycling and donating food is a priority (Filimonau & Gherbin, 2017) as 73% of unsold food that is fit for human consumption in the UK is directed to charities and animals via the Tesco chain of stores (Tesco PLC, 2018).

In Morocco, initiatives such as “Foodeals” offer promising solutions to address food waste. This technology-driven platform developed by a young scientist in 2021, allows companies to list surplus or near-expiry food products via annual subscriptions. Customers can purchase these items at reduced prices for personal use or to donate to charitable organizations.

4.6 Food waste sent to landfill

A considerable proportion estimated at around 40% of total food waste was disposed of in landfills (Table 3). This percentage is slightly higher than that reported by the Food Waste Reduction Alliance in the United States, estimated at 28% of food waste sent to landfills in 2016 by retailers (FWRA, 2016). Food waste was also higher than the proportion reported in the New Zealand retail sector estimated at 23% (Goodman-smith et al., 2020). Several factors contribute to this high rate of landfilling, including inadequate infrastructure, high transportation costs, and the absence of effective waste management systems in rural areas.

It is also of great interest to know the types of food sent to landfill as well as how to reduce food waste sent to this destination (Whitehead et al., 2013). Indeed, findings from this study revealed that vegetables, fruits, meats and fish, which are highly perishable, constitute the food categories

contributing the most to food waste sent to landfills (Table 4). This is primarily due to the lack of proper storage facilities and temperature control in rural markets. These results underline the importance of adequate infrastructure to the rural market that will help retailers minimize waste.

Bakery and grain product waste represented 6.6% of all landfilled food (Table 4). Among these, bread which significantly contributes to food waste by Moroccan citizens. Indeed, according to Moroccan Federation of Bakeries and Pastries, a number between 110 million and 120 million loaves of bread are produced per day in Morocco, of which 25% are lost and not consumed, which is equivalent to 30 million loaves per day. This situation represents a significant loss when factoring in the wasted food, money, effort, and energy. Furthermore, considering Morocco's dependency on wheat imports paid in hard currency, the impact is even more substantial. (ONICL, 2023). In their case studies of retail food waste in Italy and Sweden respectively, Cicatiello et al., (2016) and Brancoli et al., (2017), also identified bread as a common food item being often wasted due to its overproduction or poor demand. In the Austrian retail sector, it was reported that bread was available for donation at a rate higher than the demand for the food recovery sector (Schneider, 2013). These observations reveal the need to adjust bakery production programs based on sales in order to reduce bread waste. Forecasting problems have also been identified as a contributing factor to food waste by Stenmarck et al., (2011). Also, reframing the supply-demand relationship for retailers is of crucial importance.

4.7 Nutrient loss generated by food waste in the rural market

The results of this study highlight the significant loss of essential nutrients associated with food waste in the rural markets. The results revealed that the rural market represents a significant reservoir of nutrients potentially destined to be lost due to food waste generated in the rural markets. On the other hand, efforts are being undertaken globally, including Morocco, in terms of strategies, policies and investments to address nutritional deficiencies (PNN, 2019), while the latter could be avoided or at least reduced if the content of wasted foods in these nutrients was recovered. The data presented on daily retail food waste in five surveyed *Souks* reveal a substantial amount of discarded food, offering an average nutritional value per *Souk* Day of 118,173 kcal, including 7,616 g of carbohydrates, 6,026 g of protein, 6,386 g of fat, 1,579 g of fiber, 334 mg of vitamin A, 1.6 mg of vitamin D, 945 mg of iron, 21,712 mg of calcium, 1,903 mg of potassium, and 4.56 mg of iodine. These nutrient losses have significant implications for public health, especially considering the prevalence of micronutrient deficiencies, such as iron deficiency anemia, in Morocco. The estimated daily

loss of 945.9 mg of iron in the El Jadida-Sidi Bennour region is equivalent to the recommended daily intake for 59 adult women or 236 children under five years old.

If food were recovered in the same proportions as it is currently wasted, the amount reclaimed would meet the RDA for iron for 59 adult women or 236 children under five, the RDA for calcium for 24 adult women or 31 children under five, the RDA for dietary fiber for 63 adult women, and the RDA for vitamin E for 315 adult women or 946 children under five.

Furthermore, reducing food waste could help mitigate the costs associated with ongoing nutrient fortification programs in Morocco. Indeed, the iron fortification program in Morocco has cost the state approximately two billion dirhams (Gain, 2014), and an additional 6.28 million dollars for flour fortification with iron and folic acid (Banque Mondiale, 2009). By reducing food waste, valuable nutrients can be preserved, potentially reducing the need for extensive fortification programs and saving significant resources.

4 Conclusion

This study provides novel insights into the extent of food waste and associated nutrient losses in rural markets of Morocco. The study also shows that while surveyed rural market retailers appear to be participating in reducing the waste they send to landfill, the focus should be on reducing the physical amount of food waste produced at the source. To address this issue, it is essential to invest in infrastructure improvements, such as cold storage facilities and efficient transportation systems. Furthermore, raising awareness and informing retailers and integrating them into the food waste management process would likely lead to a sustainable and significant reduction in food waste in the retail sector, such as in the weekly rural *Souks*, but also throughout along the food supply chain. It will also have a significant positive impact on reducing malnutrition, economic gains, preserving natural resources and reducing greenhouse gas emissions associated with food production and landfill management. Food waste constitutes a serious issue contributing to the unsustainability of food and development in general as well as in food insecurity. To this end, considering expanding this type of study to other regions of the country is relevant to enrich and understand the practices and behaviors of populations in relation to this issue to obtain varied perspectives in order to suggest actions and strategies targeting places of action for stakeholders in this dynamic of food waste.

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