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BIOTECHNOLOGY

Food loss and waste in the central market of a developing country: The case of Merida, Mexico

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ABSTRACT. Hunger and malnutrition have been an important challenge facing the world, with food insecurity being their main contributing factor. However, as the solving strategies focus on increasing production, food losses that reduce availability for consumption and affect climate change tend to happen. In this study, the nutritional composition and microbiological quality of food losses in the central market of Merida, Mexico, were determined. The study population was composed of a set of discarded foods that were deposited in containers at the central market. Three types of sampling were obtained: for solid waste, for the calculation of the food percentage contained in the solid waste, and for chemical and microbiological analysis. The sample data was recorded and analyzed with descriptive statistics. The average solid waste generated per day was 1185.02 kg, with more than three-quarters (86.08%) of its content consisting of fruit and vegetable groups. No animal-derived foods were found among the food losses since this central market doesn't supply them. The greatest amount of protein and fiber was present in vegetables, while fruits had the greatest amount of moisture and carbohydrates. The presence of microorganisms, mainly yeasts, was higher than the established limit, making the food unsuitable for human consumption. However, it was found to be a good source of lipids and organic matter, making them useful for composting, biofuel production, or the extraction of bioactive compounds.

Key words: Food insecurity; Hunger; Food systems; Food supply chain; Waste management.

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Introduction

Food loss and waste (FLW) is a major issue due to its high socioeconomic costs and its relationship with waste management and climate change challenges. FLW causes considerable losses of invaluable resources and contributes to environmental degradation. It also becomes a moral issue, as almost 12 percent of the world's population suffers from hunger (Lohnes &Wilson, 2018).

The first global estimate of food loss and waste emphasized that one-third of all food produced in the world is being lost or wasted, which translates to an annual output of approximately 1.3 billion metric tons of organic waste. This loss of nutrients and energy would be equivalent to feeding approximately 1.9 billion people in the world. With appropriate policy interventions, about 50% of this loss could have been prevented (Hoehn et al., 2023). The implementation of the Sustainable Development Goals (SDGs) Agenda at a global level in 2015 and SDG 12.3 in particular, which aims to halve food loss and waste by 2030, has been highlighted as another important milestone that sparked a surge in scientific studies related to FLW (Spang et al., 2019).

The main factors responsible for FLW include poor management of perishable foods, stakeholder attitudes, buyer-supplier agreements, and supply chain disruptions. Addressing these issues will help to better define the existing practices in the food supply chain for the mitigation of waste and the rescue of large volumes of food intended for consumption by the population (Chauhan et al., 2021). According to the World Bank, Mexico has food losses at all stages of the supply chain. Of the food produced for human consumption, 34.5% (20.3 Gt) is lost. Not only does this cost the country 23.38 billion dollars, but it also generates more than 36.9 Gt of CO_2e emissions and causes the loss of more than 39.8 billion m^3 of fresh water (Aguilar-Gutiérrez, 2021). Food loss occurs in the pre-harvest and post-harvest stages, distribution, and wholesale and retail sales, with markets as the places where this phenomenon is most frequent (Balaji & Arshinder, 2016).

In Mérida, Mexico, food losses and waste are considered part of the solid waste generated in the city and are managed using open dumps as the final disposal method. Due to its simplicity, the landfill is the option that has been considered to replace open dumps, but this method could have a high impact in terms of carbon emissions since solid waste management systems contribute significantly to greenhouse gas emissions (Sauri-Riancho et al., 2013)

World hunger, food insecurity, and climate change are some of the most challenging issues related to food systems, making it essential to assess and reformulate these systems with long-term sustainability in mind. Minimizing food loss is one of the main urgent challenges to achieving food security and establishing sustainable food systems in contemporary society. Data on food loss in developing countries in all different stages of the food supply chain is scarce, and yet, these countries have the least number of policies and resources to prevent food loss (López-Sánchez et al., 2021).

Mexico is emerging as a country vulnerable to climate change and land use change, which are already affecting food production and consequently the food security of its population due to some degree of degradation in their soils, and the territory being prone to water and wind erosion. In addition, there is a public health crisis due to the increase in diet-related diseases, including malnutrition and obesity (Denham & Gladstone, 2020). Mérida has adequate social and environmental conditions for food production since it's a municipality with a low index of marginalization and has a diversity of productive activities. However, food security is a problem that requires an interdisciplinary approach due to existing evidence that there is no food availability problem, according to Cruz-Sánchez et al., (2024).

Food insecurity in Mexico is mainly caused by the lack of resources to acquire quality food, and exacerbated by food inflation, widespread unemployment, and low education. This situation is intensified by environmental impacts and an inadequate food supply that does not meet health standards (Monroy-Torres et al., 2021).

In the Southeast of Mexico, it has been shown that two opposing chronic conditions products of poor nutrition converge alarmingly in the population: malnutrition, which mainly affects children, and excess weight, which has worsened in the adult population; this has been called the 'double burden' of malnutrition combined with overnutrition (Leatherman et al., 2020). Children in rural areas suffer from low weight, short stature, and emaciation, while in urban areas the population suffers from obesity, diabetes, and hypertension (Barbosa-Martín et al., 2016). The latter is due to the commercialization of food systems, the increased distribution and consumption of commercialized foods, especially 'junk food,' which are rich in calories but deficient in micronutrients (Leatherman et al., 2020).

In Merida, Mexico, there is a central market that receives tons of food for wholesale and retail sales daily. Because of this, and since there are no records of its food losses, this study quantified the losses from this main distribution center in Merida, Mexico, determining the quantity, variety, chemical components, and possible loss associated with microbial growth.

Materials and methods

The study was conducted from June to August 2019 at the central market in Merida, Mexico, located at the coordinates 20°59'16.3'N 89°39'50.1'W (Figure 1), where the predominant climate is tropical subhumid. The climatic conditions during the experimentation were an average temperature of 36 °C, humidity of 45%, and rainfall of 125 mm. The central market is a public market with approximately 250 vendors, with a land area of 1.6 hectares divided into retail sales areas, wholesale sales areas, refrigerated and room temperature warehouses, cold rooms, food loading and unloading platforms, parking lots, green areas, administrative offices, and services, among others.

Figure 1. Images of the case study location, the Central Market of Merida, Mexico and some sales areas.

Food waste and losses are placed in 200-liter plastic containers in a waste area at room temperature, with a high health risk since they are stored without hygienic or sanitary care (Figure 2). They have no economic value since they are considered part of the solid waste or garbage generated by the market.

Figure 2. Food loss and waste in containers at the Central Market of Merida, Mexico.

In the present research, three types of samples were taken for each sampling: a) Sampling for solid waste, b) Sampling for the calculation of food percentage contained in the solid waste, and c) Collection of food samples for evaluation of the proximal chemical composition and microbiological analysis.

Sampling for solid waste

The net weight data reported in the 'Weighing scale entry forms' was considered. The administrative staff of the central market provided the information by e-mail after request. Given that the containers at the central market are collected for disposal every three to four days, 10 samples of 50 kg each were taken on randomly selected days during the study period. Each sample was collected from food generated during the day, and the working hours were set from 10:00 to 12:00. For each day, the date of data collection was noted, and the prevailing weather conditions on the day of sampling (temperature and the presence or absence of rainfall) were subsequently consulted in the electronic records of the Comision Nacional del Agua (CONAGUA). The physical appearance of the food (color, odor, taste, and texture) was also registered. The descriptive statistics: mean, standard deviation, and confidence interval for the mean were obtained from the data collected.

Sampling for the calculation of food percentage contained in the solid waste

The guidelines established in the following standards were followed to obtain the samples: Mexican Standard NMX-AA-15-1985 for the quartering method, Mexican Standard NMX-AA-19-1985 for *in situ* volumetric weight, and Mexican Standard NMX-AA-22-1985 for product selection. The procedure used for data collection was based on that established by the standard NMX-AA-15-1985, consisting of filling polyethylene bags with 50 kg of solid waste from 10 FLW containers or trucks of food waste and later emptying them to form a pile on a 4 m^2 flat horizontal area of polished cement under roof. The quartering method was performed using 50 kg of food and selecting only one quarter. Each bag was contained within a 200-liter capacity cylindrical metal container. The pile of solid waste was shoveled until homogenized and divided into four approximately equal parts. One of the parts was randomly selected, and the others were discarded. For the food loss percentage calculation, the guidelines indicated in the standard NMX-AA-22-1985 were followed. The food was separated, placed in polyethylene bags, and weighed according to the standard NMX-AA-19-1985. The mean, standard deviation, and confidence interval of the data were calculated.

Recollection of samples for laboratory analysis: proximate and microbiological

The recollection was performed following the guidelines established in the standard NMX-AA-15-1985, which indicates that 10 kg of food waste must be collected for the physical, chemical, and microbiological analyses. For this, each sample was randomly selected through a distribution on a previously cleaned 1 m^2 flat surface. This distribution consisted of 10 plots on each side (100 in total), spreading the 10 kg of food between each of them. The sample was selected in duplicate from 15 plots using an Excel spreadsheet that randomly generated the plot chosen. The samples were collected in polyethylene bags and were placed in an isothermal cooler with ice for transport to the laboratory, where they were stored at 4°C for a maximum of 48 h until analysis. Samples were analyzed in triplicate at the same time to ensure uniform conditions and comparability.

Experimental design

The experiment was performed using totally randomized designs. Sample data was recorded and processed with descriptive statistics to obtain the values of the central tendency and dispersion. The selection criteria were as follows:

Inclusion: Solid food waste of the day deposited in the food waste container of the central market, food waste of the day that was randomly selected after applying the method of quartering, and collection of samples for laboratory analysis.

Study variable: Food loss, understood as food deposited in the central market dumpster and characterized as unsuitable for commercialization.

Techniques for variable characterization

Three methodologies were used: a) weight percentage measurement, b) proximate chemical analysis (PCA), and c) microbiological analysis.

Determination of food loss percentage. The percentage by weight of food waste as part of the solid waste was quantified according to the techniques described in the Mexican Standards indicated above.

Proximal chemical composition determination (PCA). Proximal chemical evaluation was performed according to the methods established by the Association of Official Analytical Chemists (Association of Official Analytical Chemists [AOAC], 2016). The moisture content was measured as a function of the weight loss of the sample after drying it in a convection oven at 110 °C for 2 h. The fat content was determined by extraction with hexane for one hour with a Soxtec system (Tecator, Höganäs, Skåne län, Sweden). The amount of ash or mineral residue was measured based on the weight of the sample after incineration at 550 °C for 2 h. The nitrogen (N_2) content was quantified with a Kjeltec digestion system (Tecator, Höganäs, Skåne län, Sweden) using cupric sulfate and potassium sulfate catalysts. Protein content was calculated as nitrogen × 6.25. For crude fiber, the sample was digested with 1.25% sulfuric acid and then with 1.25% sodium hydroxide. The part consisting of fiber was obtained from the residue by drying to a constant weight, calcining, and reweighing. Carbohydrate content was estimated as nitrogen-free extract (NFE), as the difference between the sum of protein, fat, ash, and crude fiber contents.

Microbiological evaluation: For the analysis of microbiological quality, the methodologies stated in the Mexican Official Standard NOM-210-SSAI-2014, Products and Services. Microbiological test methods, Determination of indicator microorganisms, Determination of pathogenic microorganisms, were used. Initially, the samples were prepared and diluted in accordance with the provisions of the standard NOM-110-SSA1-1994. The solid samples were uniformly mixed and liquefied with sterile water for 2 min and then proceeded to decimal dilutions. The determination of total aerobic bacteria was done by the pour-plate in agar technique for standard methods according to the standard NOM-092-SSA1-1994 and incubated for 48 h at 35±2 °C. The methods indicated by the standard NOM-111-SSA1-1994 were used to determine fungi and yeasts, using the pour-plate technique, and counting the colonies that developed on acidified potato dextrose agar and incubated at 25±2 °C. The techniques indicated in the standard NOM-113-SSA1-1994 (SSA, 1994d) were used to estimate the amount of total coliform bacteria.

Statistical analysis

The results obtained were analyzed with descriptive statistics using the statistical Statgraphics Centurion software version 19.

Results and discussion

Quantity of solid waste disposed per day

The minimum and maximum values for solid waste weight found in the central market of Merida, Mexico, were 808.57 kg and 1873.33 kg, respectively. The information obtained from the calculation of statistical estimators for solid waste was a mean of 1185 kg, a standard deviation of 333.61, and a 95% confidence interval between 979.36 and 1398.83 kg.

According to the Secretaría de Economía (2020), the amount of food moved daily in Mexico is 87 tons. Therefore, the amount of solid waste disposed of represented 1.36%. Similarly, in the wholesale market of Xalapa, Veracruz, a daily waste of 1.7 tons was calculated, consisting mainly of fruits and vegetables. Vendors indicated that they do not know the factors responsible for this; therefore, there is a need to review the relevant public policies to improve their coordination and solve the problems at the site (García-Pérez et al., 2020).

According to Prado-Salazar et al. (2016), in Jalisco, the amount of solid waste collected per day is approximately 7.2 tons, of which 65% is organic waste. Of this, 60% corresponds to vegetables and 40% to fruits. In Guadalajara's central market alone, approximately 36.3 tons per day correspond to fruit and vegetable waste. The most recent data from the Gobierno del Estado de Jalisco (Soluciones Integrales para la Problemática Ambiental [SIPRA], 2019) indicates a significant increase in this central market to 110 tons, making the amount of waste more than 90 times higher than that found in Merida. Thus, with appropriate technology, macro or micronutrients could be indirectly exploited from the FLW in central markets.

According to the Gobierno del Estado de Yucatan (2024), the estimated amount of solid waste in Merida is 1265 tons daily. If we consider that, according to the report made for the World Bank by Kaza et al., (2018), about 42% of these correspond to food waste without considering yard waste (since together they represent 52%), the food waste would be 531 tons daily. This indicates the huge potential for creating policies and technologies for the utilization of food waste. It should be noted that it is likely that, in Merida's central market, not all of the food discarded is deposited in the containers, as it may be donated to civil associations like food banks and soup kitchens, may be destined for animal consumption, or sold as second quality food at very low prices.

Percentage of food contained in solid waste

As for the results corresponding to the amount of food (%) found in the solid waste samples, the information obtained from the statistical estimators is shown in Table 1. Data were the result of weekly analyses of food losses and waste.

According to the above data, it was observed that most of the solid waste was composed of fruits and vegetables (86.08%) and a smaller percentage of other foods, such as potatoes and avocados, which were accounted for as separate groups, under cereals and tubers and oils and fats, respectively. No animal-derived foods were found among the food losses since this market doesn't supply them. Related to this, in a record made by the authorities of the central market of Mexico City, it was mentioned that an average of 87.04% of the solid waste discarded was composed of food waste such as fruits, legumes, and vegetables (Muñoz-Cadena & Morales-Pérez, 2018), which was similar to the results obtained in the present research.

Table 1. Statistical estimators of the food percentage contained in solid waste samples from the central market of Merida, Yucatan*.

Estimator	Total weight of solid waste (kg)	Weight of fruits and vegetables (kg)	Percentage of fruits and vegetables (%)
Mean	12.43	10.68	86.08
Standard deviation	0.42	0.66	7.45
Minimum value			76.85
Maximum value			95.56
Confidence interval at 95%.			(80.57 to 91.60)

*FLW were analyzed weekly.

Rizo-Mustelier & Vuelta-Lorenzo (2021), from September 2018 to April 2019, conducted an investigation in the agricultural state market 'La Vallita,' located in Santiago de Cuba, to determine the losses of agricultural products. Similar to the present investigation, their results indicated that the largest amount of losses occur with fruits and vegetables with 58%, equivalent to approximately 869.42 kg, followed by roots and tubers with 28% (419.72 kg), cereals with 6% (89.94 kg), meats with 5% (74.95 kg), grains with 2% (29.98 kg), and finally condiments, colorings, spices, etc. with 1% (14.99 kg). Sáez et al. (2018), reported similar results in studies conducted at country level in Chile, finding that fruits and vegetables are generally the products that are the most lost worldwide.

In the study conducted by Prado-Salazar et al. (2016) in the central market of Guadalajara, Mexico, it was reported that the waste discarded came from vegetables and fruits. This quantity was lower than that found in the present investigation, and a factor that might be related to this is that Guadalajara's central market has a refrigeration service, while Merida's central market has no record of this service being provided.

The FAO notes that, in many countries, large quantities of food are lost during storage, often due to poor infrastructure and facilities at food wholesale and retail outlets, inadequate storage, and especially the lack of cold storage facilities (Food and Agriculture Organization of the United Nations [FAO], 2020). Temperature control is essential for maintaining the quality of perishable products, such as fruits and vegetables, since it prevents the occurrence of degenerative processes, such as the proliferation of microorganisms, softening, and water loss, among others.

The physical conditions of the lost or discarded food samples were diverse, and Table 2 shows those that predominantly prevailed. These were the result of weekly observations. The main characteristics observed were dark spots on the surface of the food and bad odor. These physical characteristics may be associated with the climatic conditions of high temperature and rainfall observed during the recollection process of the food waste samples. During the study, mean temperatures were between 35.6 and 36.6°C, and rainfall was frequent, with rainfall values of 102.1 and 148 mm.

Table 2. Physical characteristics of food samples discarded in the central market of Merida, Yucatan.

Food	Physical characteristics*
Banana	Browning, soft and watery texture.
Apple	Browning on the surface, soft texture, and foul odor
Lemon/Tangerine	Soft and watery texture.
Mammee	Soft surface with indentations.
Cantaloupe	Dehydrated skin, indentations, and bad odor.
Mango	Dark spots on the surface.
Tomato	Cracks, indentations, and damage to the exterior surface.
Carrot	Soft texture, rough and dark skin.
Potato	Wrinkled surface, with brown spots.
Avocado	Browning on the surface and inside of the fruit.

*Characteristic were analyzed weekly.

Nutritional and microbiological composition of food loss

Chemical composition of foods

According to Table 3, fruits and vegetables were the foods with the highest losses. This corresponds with the FAO's State of World Food Report, which states that 15% of fruit and vegetables are wasted at the wholesale and retail level in all regions of the world, except sub-Saharan Africa, where wastage levels reach 35% (FAO, 2019b). Regarding the foods with the highest losses, it was observed that among the fruits were lemon, mammee, mango, tangerine, apple, melon, and banana, and among the vegetables were onion, jicama, romaine lettuce, radish, tomato, and carrot. In this regard, in a study presented on World Food Day concerning food waste in Mexico, several of the foods identified as losses in this research coincided with the list of foods with the biggest losses in the country, particularly mangoes, apples, avocados, tomatoes, onions, and cantaloupes (Kánter-Coronel and Ponce-Sernicharo, 2016). This was confirmed by researchers from the Instituto Nacional de Ciencias Medicas y Nutricion Salvador Zubiran (INCMNSZ) and the Instituto Tecnologico y de Estudios Superiores de Occidente (ITESO), who indicated that avocado, mango, and apple are some of the foods that are lost the most in the country (Saucedo, 2020).

The greater variety of food losses in this research could be attributed to the differences in food production between regions of the same country and the transfer to different central markets for commercialization, as indicated by the FAO (FAO, 2019a). Foods grown in different states of the country, such as bananas (Tabasco), onions (Mexico City), tomatoes (Campeche, Mexico City, or both), and carrots (Mexico City, Puebla, or both), were the most lost. This situation was also observed in the central market of Puebla, Mexico, where it was found that tomatoes from states such as Baja California or Sinaloa tended to be the main component of food waste sent to disposal compared to locally grown foods such as nopal (cactus) (Saucedo, 2020). As for the percentage of nutrients, the mean protein and fat contents were 5.7% and 1.04%, respectively. In the case of carbohydrates, which were estimated as nitrogen-free extract (NFE) and fiber, the means were 7.18 and 8.94%, respectively. Regarding the level of ash or mineral residue, the highest content was found in avocado, with 1.4%. In general, carbohydrates were the nutrients with the highest losses. This coincided with the Mexican Food Equivalent System (SMAE), which indicates that the fruit and vegetable food groups are both characterized by a high carbohydrate content.

Table 3. Nutrients on a wet basis (%) obtained from food samples from the central market of Merida, Yucatan, Mexico.

Number of samples	Percentage of total samples	Food group*	Foods	Weight of the sample	Protein (%)	Fat (%)	NFE+ (%)	Fiber (%)	Ash (%)	Moisture (%)
7	46.6	Fruits	Lemon, Mammee, Mango, Tangerine, Apple, Cantaloupe, and Banana.	17.2	3.9	0.9	8.9	8.0	0.8	77.5
6	40.2	Vegetables	Onion, Jicama, Romaine Lettuce, Radish, Tomato, and Carrot	19.1	7.9	0.6	6.2	13.6	0.3	76.8
1	6.6	Cereals and tubers	Potato	2.9	1.1	0.2	4.8	8.2	0.6	79.7
1	6.6	Oils and Fats	Avocado	2.0	7.7	7.6	5.2	17.4	1.4	60.7
Weighted arithmetic mean					5.7	1.04	7.18	8.94	0.54	76.6

* Classification of the Mexican Food Equivalent System. +Nitrogen Free Extract.

The fiber content was higher in both the oils and fats group (avocado) and in the vegetable group, as expected, according to the data reported in the SMAE (Pérez-Lizaur & Palacios González, 2022).

For the protein content, despite being low, it was present in the vegetable group and the oils and fats group, particularly due to the composition of the avocado. In the case of lipid content, it was scarce due to the chemical nature of the foods evaluated within the fruit and vegetable groups; however, it was abundant when quantified in the avocado. When the samples' moisture content was evaluated, values between 60.7% and 79.7% were found; moisture content of fresh fruits and vegetables should be between 85% and 98%. For instance, Paéz & Salazar (2020), in a study from a wholesale market in Ambato, Ecuador, reported moisture values between 89 and 95%; however, the range obtained in the present research was lower, possibly due to the temperature conditions that prevailed during the study period.

Reducing food loss and waste has an impact on achieving the Sustainable Development Goals (SDGs) related to environmental sustainability and food and nutritional security. Consequently, the generation of FLW also has a negative impact on the realization of the human right to adequate food (Manzoor et al., 2024).

Food availability and nutrient deficiencies are not a problem in Mérida, Mexico, since the environmental and social conditions are suitable for producing food from agriculture and livestock, and there are sufficient food outlets to cover the caloric and protein demand of the population. The issue of food insecurity may be due to other causes such as low education, widespread unemployment, and food inflation (Cruz-Sánchez et al. 2024).

In their specific study of the population of the municipality of Mérida, Barbosa-Martín et al. (2016) reported a general prevalence of malnutrition in schoolchildren, teenagers, and adults of 3.3%, 22%, and 1.2%, respectively. On the contrary, health issues are rooted in excess weight, considering overweight and obesity, where the proportion found in the preschool population was 16.1%, in the school population 51%, in adolescents 49.5%, and in adults 77.9%, respectively. The main problem for the population of Mérida lies in 'overnutrition,' or surplus calorie consumption that leads to overweight, obesity, and diabetes due to poor eating practices due to the consumption of Westernized diets.

The use of FLW has also been proposed for obtaining bioactive compounds from the husks, seeds, and pulp of food waste (Nirmal et al., 2023) since they represent a great contribution of physiologically functional components like dietary fiber, oils with polyunsaturated fatty acids, and biologically active molecules such as phenolic compounds. These latter could have beneficial effects on the health of consumers, particularly due to the presence of phytochemicals that have antioxidant effects that are helpful in the prevention of chronic diseases, including cardiovascular, inflammatory, neurodegenerative, and cancer, as well as diabetes and senescence (King-Loeza et al., 2023).

According to Ramírez et al. (2018), food waste and its energy, protein, and vitamin content can be successfully used for many purposes, and anaerobic preservation methods or silage technologies could be used. The discarded food from Merida central market could be evaluated for these uses and as a by-product for animal feed once its microbial load and potential decomposition that could affect consumption by animals have been reduced. It could also be used as compost due to its high content of fermentable carbohydrates, which would facilitate its fermentation during the composting process under controlled conditions. Another potential use for valorizing food waste would be the production of biogas due to its high organic matter content, which could propitiate high yields during the production of this biofuel, as reported by Solarte-Toro et al. (2018), in their studies of anaerobic digestion of food and pruning waste.

Microbiological evaluation

The content of microorganisms in the lost fruits and vegetables was evaluated by comparing the average results of aerobic bacterial counts, total coliforms, and molds and yeasts with their respective microbiological limits (Table 4).

Table 4. Microbiological quality of food loss from the central market of Merida, Yucatan, Mexico.

Result per food group (CFU g^{-1})																
Analyzed Parameter	Vegetables n = 6						Fruits n = 7							C & T n = 1	O & F n = 1	Micro-biological limit
Samples	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_1	S_1	
Aerobic Bacteria	740	800	4400	3700	860	740	60	280	320	40	60	100	150	140	110	10^5 CFU g^{-1}
Molds	7400	8000	2200	2400	2500	2500	600	800	2700	1800	2300	2500	2400	1200	1300	10^4 CFU g^{-1}
Yeasts	21000	16300	16300	19500	21700	16100	17100	18100	15000	16700	20800	19200	19100	14000	11000	10^4 CFU g^{-1}
Total Coliform Bacteria	2300	2200	3400	2400	950	870	120	240	360	240	260	240	1050	200	210	10^4 CFU g^{-1}

C & T: Cereals and Tubers. O & F: Oils and Fats.

The highest number of colony-forming units per gram (CFU g^{-1}) for aerobic bacteria was observed in the vegetable group, with a value of 4,400 CFU g^{-1}. The lowest amount was found in the fruit group, with 40 CFU g^{-1}. When comparing the results with the microbiological limit (10^5 CFU g^{-1}) established to outline the hygienic-sanitary acceptability of food of vegetable origin, it was observed that all the samples of the food waste under study were below the permitted limit (Food and Agriculture Organization of the United Nations [FAO] & World Health Organization [WHO], 2023). Regarding the presence of molds, food samples from wasted vegetables had the highest amounts, from 600 to 8000 CFU g^{-1}. However, in none of the cases did they exceed the microbiological limit established (10^4 CFU g^{-1}) to define their hygienic-sanitary acceptability. Similarly, considering the levels of molds, the food loss under study was acceptable for consumption.

In the case of yeast count, all the samples presented values that exceeded the maximum limit of 10^4 CFU g^{-1}. This is consistent with the physical characteristics of food waste, such as browning and foul odor, as an indication of fermentation spoilage processes due to these microorganisms. For this, it is not possible to conclude that the food waste in this study could be destined for human consumption. The presence of yeast damage in both fruits and vegetables is common after the harvest period and is linked to soil being the main reservoir of yeast in the environment, with food being contaminated by contact with soil and its decomposition being accelerated by the high content of sugars, water, and favorable environmental conditions. Karanth eta al. (2023) reported the presence of yeasts of the genera *Saccharomyces, Hanseniaspora, Pichia, Kloeckera, Candida,* and *Rhodotorula* in fruit and vegetable loss and waste, which, in addition to causing spoilage, represent a risk of disease for potential consumers.

Considering only the levels of bacteria and molds, the food waste in this study presents a hygienic-sanitary acceptability that could allow its potential consumption in human and animal feed. However, due to the presence of yeasts above the established microbiological limit, they represent a risk to the health of consumers, and therefore the lost and wasted food from Merida Central Market is not recommended for human consumption.

Although none of the samples evaluated exceeded the microbiological limit of 104 CFU g^{-1} for total coliform bacteria, the deterioration of food waste by the action of yeast would favor the growth and development of coliforms that could contribute significantly to the risk of foodborne diseases such as gastroenteritis, dysentery, typhoid fever, and cholera, among others. This indicated a lack of hygiene in handling, in production, and inadequate storage operations (Ghosh et al., 2020). The disease-causing pathogens could potentially infect animal or human consumers; this is of paramount concern in food waste reuse. In order to control the biosecurity associated with microorganisms, some treatments are usually used, including boiling, chemical additives, ensiling, composting, or heat methods (Jin et al., 2012).

Conclusion

Daily, an average of 1185.02 kg of solid waste is disposed of at the central market in Merida, Yucatan, Mexico. More than three-quarters of this solid waste is composed of food waste, particularly fruits and vegetables. The foods with the greatest losses are fruits such as lemon, mammee, mango, tangerine, apple, melon, and banana, and vegetables such as onion, jicama, romaine lettuce, radish, tomato, and carrot. Foods of animal origin were not found since this central market doesn't supply them. Vegetables were found to have a higher protein and fiber content, while fruits had high levels of water and carbohydrates. The highest lipid content was found in avocado, classified in the oils and fats group. Aerobic bacteria, fungi, and total coliforms in the foods with the highest wastage were below the permissible limits. However, the yeast content was above the microbiological limit established for good hygienic-sanitary quality. Therefore, food discarded at the central market cannot be considered fit for human consumption, but it can be a sustainable alternative to produce compost, biofuel, and for obtaining bioactive compounds.

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