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Diagnosis and strategies for kitchen and food waste management in an institutional canteen in Buenos Aires, Argentina

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Abstract. The classification and quantification of kitchen and food waste is a necessary strategy to improve the sustainability of waste management. The objective of this study was to quantify and describe the solid waste generated in the kitchen (food processing zone) and canteen of an official institution over the course of a year. A waste sampling protocol was established, which made it possible to identify, classify and characterize the generated waste. It generated 802.4 kg of total waste/day, representing 0.34 $kg.day^{1}.person^{-1}$, with similar averages in the processing and canteen zones and greater generation during the main meals. Dry (15%), wet (73%) and mixed (11.8%) wastes were identified. Dry waste was generated mainly in the processing area, and to manage it during the preparation of the main menu, the practices included in the 4Rs are proposed. The strategy of source separation of said area will allow a 93.5% reduction of mixed waste. The generated wet waste was 587.77 kg/day. Among other characteristics, wet waste showed acid pH, high moisture content, balanced lignocellulose biomass composition and C/N ratios within the range considered optimal for biological transformation such as aerobic composting and/or anaerobic digestion or fermentation. In addition, it is rich in protein and fiber, which is why it is proposed to manufacture animal feed as an alternative destination for digestion processes. This study identifies great potential for sustainable management of food loss and waste, in accordance with the objectives of the circular economy.

[Keywords: sampling protocol, circular economy, waste management]

Resumen. Diagnóstico y estrategias para gestionar residuos de cocina y alimentos en un comedor institucional en Buenos Aires, Argentina. Clasificar y cuantificar los residuos de cocina y alimentos es una estrategia necesaria para mejorar la sostenibilidad de la gestión de residuos. El objetivo de este estudio fue cuantificar y describir los residuos sólidos generados en la cocina (zona de procesamiento) y el comedor de una institución oficial a lo largo de un año. Se estableció un protocolo de muestreo de residuos que permitió identificar, clasificar y caracterizar los residuos. Se generaron 802.4 kg de residuo total/día, lo que representa 0.34 $kg.día^{-1}.persona^{-1}$, con promedios similares en las zonas de procesamiento y comedor; la generación fue mayor durante las comidas principales. Se identificaron residuos secos (15%), húmedos (73%) y mixtos (11.8%). Los residuos secos se generaron sobre todo en la zona de procesamiento, y para gestionarlos durante la preparación del menú principal se proponen las practicas incluidas en las 4R. La estrategia de separación en origen en dicha área permitiría reducir el 93.5% de los residuos mixto. El residuo húmedo generado fue 587.77 kg/día; entre otras características, presentó un pH ácido, un alto contenido de humedad, una composición equilibrada de biomasa lignocelulósica y relaciones C/N dentro del rango considerado óptimo para transformación biológica como compostaje aeróbico o digestión o fermentación anaeróbica. Además, es rico en proteínas y fibras, por lo cual se propone fabricar piensos como destino alternativo a los procesos de digestión. Este estudio permite identificar un gran potencial para la gestión sostenible de la pérdida y el desperdicio de alimentos, en línea con los objetivos de la economía circular.

[Palabras clave: protocolo de muestreo, economía circular, gestión de residuos]

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Introduction

Food loss and waste (FLW) is a global problem that generates significant ecological, social and economic impacts and represents one of the main issues addressed by global multilateral organizations, which have estimated that a large proportion of the food produced worldwide is lost or wasted in the production, marketing and consumption chains (Gustavsson et al. 2011). There are different approaches to its definition, considering the stage at which it is generated; it is called loss or spoilage when it occurs in the production, post-harvest and processing stages, while in the marketing and final consumption stages the term waste is used (Parfitt et al. 2010; Yu and Li 2020). Other authors distinguish both terms by the nature of their causes, attributing behavioral causes to wastage (HLPE 2014). On the other hand, surplus is defined as all food produced beyond our nutritional needs, while waste is the product of this surplus (Papargyropoulou et al. 2014).

Addressing this issue is current and crucial to support policies that attempt to achieve the United Nations Sustainable Development Goals, specifically related to Goal 12 'Responsible production and consumption'. If the targets established within this goal are considered, 12.4 and 12.5 stand out, respectively, which seek to achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, and to significantly reduce waste generation through prevention, reduction, recycling and reuse activities, respectively (UN Department of Economic and Social Affairs 2015).

Different sectors of society and authorities have shown willingness to improve FLW management and reduce its generation. Therefore, it is essential to know the composition and quantity of such waste, which allows decision makers to understand the problem more clearly and justify the necessary investments. In Latin America, 127 million tons of food are lost and wasted annually, so the region has set the goal of halving per capita ADP by 2030 (FAO 2016). In Argentina there are debates and some public policies to achieve this goal. Among them, in 2017, the National Network for the Reduction of Food Loss and Waste was created, within the framework of the National Program for the Reduction of Food Loss and Waste. More recently, the 'Donal Law' was amended, which will allow companies to donate more food adequate for consumption, whereby increasing initiatives, campaigns and developments are expected to achieve these objectives (Law 27454 and Decree 246/2019).

Despite the importance of knowing the types and quantities of food and food waste, there are no international standard methods for sampling and characterization (Dahlén and Lagerkvist 2008; Lebersorger and Schneider 2011). For this reason, there is a diversity of approaches that generate uncertainties and difficulties for comparisons between cases (Guerin et al. 2018; Elimelech et al. 2019). The studies conducted differ in data collection methods and procedures, waste categories, type of generating source and implicitly in the social context. Some studies conducted in collective canteens indicate high variability in waste generation data, both due to measurements over short periods of time or the existence of other conditioning factors (Engström and Carlsson-Kanyama 2004; Secondi et al. 2015; Wilkie et al. 2015; Eriksson et al. 2017).

Typical characteristics of domestic food waste are high moisture content, high content of organic components and low calorific value (Li et al. 2013). It is therefore appropriate to manage them as organic waste and to orient efforts on the 4R principles (reduce at source, reuse, recycle and recover before disposal), where quantification and characterization of waste properties can provide an estimation of the potential mass of materials available for it (Zeng et al. 2005; Chang and Davila 2008). While the household sector represents a significant source of waste at the consumer level, institutions that provide food services are also an important source of waste (Cordingley et al. 2011). This is the case of the Río Santiago Shipyard employee canteen that processes and dispenses food. The main objective of this study is to quantify and describe the solid waste generated in the kitchen and dining room of the Río Santiago Shipyard over the course of a year. For this, it is intended to establish a sampling protocol and indicate destinations of the waste according to the 4R criteria.

The general objective of the research is achieved by answering two specific research questions: a) Are there any differences between the quantities and qualities of waste generated in the different sectors of the studied area, which would allow the identification of flows for subsequent treatment? b) Could a sampling protocol be established that complies with the premises of practicality and efficiency, to cover all the waste generated in all areas and at different times? This work represents an opportunity to implement measures aimed at preventing and/or reducing food waste reinforced by a society that demands public and private institutions to develop initiatives that contribute to achieve sustainable development (Wilkie et al. 2015; Derqui and Agustín 2016).

Materials and Methods

Study area

The case study is located in the Río Santiago Shipyard, located in Ensenada, province of Buenos Aires, a state-owned shipbuilding, ship repair and metal-mechanical construction company, with more than 229 hectares, within which the Río Santiago Shipyard Technical School operates. It has a dining room that processes and dispenses food for more than 3000 persons per day, including workers and students.

Information gathering

Two visits were made to the Río Santiago Shipyard, prior to the sampling stage, to obtain basic information that made it possible to differentiate the zone where solid food waste (SW) is generated, the times and types of waste. Based on the information collected, a sampling protocol was established.

Sampling protocol

Waste classification was based on a unified protocol developed for this study, with detailed instructions in order to minimize subjective judgments. Zones, categories and times of waste generation were identified. Two SW generation zones were established: the food processing zone (PZ) and the canteen zone (CZ), where food was dispensed in polycarbonate trays. The waste collected was characterized into dry solid waste (DSW), wet solid waste (WSW) and a mixture of DSW and WSW (Mixture) that could not be separated or identified due to undifferentiated disposal. The times of SW generation were during main meals (i.e., lunch and dinner) and secondary meals (i.e., breakfast and snack). During lunch, three shifts of food dispensing were distinguished, and the results were presented as the total sum; dinner was distributed in a single shift due to the lower number of diners. Sampling was performed on 6 dates covering different seasons of the year (September, November and December 2016 and April, June and July 2017). The summer recess months were not counted. To meet the proposed objective, the data are presented as the average of all dates, not considering the variability between dates.

SW from the PZ, due to hygiene and safety reasons, were collected from bags placed in 1100 L plastic containers located outdoors. On each sampling date, three bags were collected (out of a total of 17) where the waste was identified and weighed, and the Mixture was set aside to form a composite sample. At CZ during lunch and dinner, on each sampling date, 30 samples were collected random at the end of the meal during the different shifts, the waste was sorted and weighed, and the Mixture was also set aside to form a composite sample. To calculate the total generation of each type of SW, was multiplied by the total number of persons. To determine the generation of SW from breakfast and snacks, the waste was weighed in bags placed in containers with lids located outdoors.

Chemical determinations were conducted on the composite samples of WSW from CZ and PZ, on two sampling dates, November and December. pH, dry matter %, moisture %, total carbon, total nitrogen, lignin, cellulose, hemicellulose, ash % and acid detergent insoluble fiber (ADF%) and neutral detergent fiber (aFDN%) were determined. The protein content was obtained by multiplying the nitrogen content by 6.25. The methodologies are described in AOAC (1990) and Ankon (2005). Statistical analysis of the data was elaborated using Infostat (Di Rienzo et al. 2014). A descriptive analysis of waste generation was performed, and hypothesis contrasts (statistical significance $P<0.05$) data were analyzed by ANOVA. Differences between means were determined using LSD Fischer test.

Results

Daily waste generation was 0.34 kg/person (±0.16), results that are within the range found by Wang et al. (2019), in which college cafeterias generate a range of 0.13 to 1.63 kg.person^{-1}.day^{-1}, and restaurants, from 0.21 to 0.78 kg.person^{-1}.day^{-1}. According to generation zone, the daily averages were similar ($P<0.05$), 0.175 and 0.17 kg/person, in PZ and CZ

Table 1. Daily generation (kg/day) of solid waste in the kitchen and canteen zone (n=18).
Tabla 1. Generación diaria (kg/día) de residuos sólidos en zonas de cocina y comedor (n=18).

Solid Waste	Processing zone		Canteen zone				Total
	Main Meal	Secondary Meal	Main Meal		Secondary Meal		
			Lunch	Dinner	Breakfast	Snack	
DSW	70.75	ND	29.3	5.9	14.6	1.02	121.57
WSW	194.97	38	295.7	59.1	ND	ND	587.77
Mixture	89.32	ND	ND	ND	5.84	0.41	95.57
Total	355.04	38.00	325.00	65.00	20.44	1.43	804.91

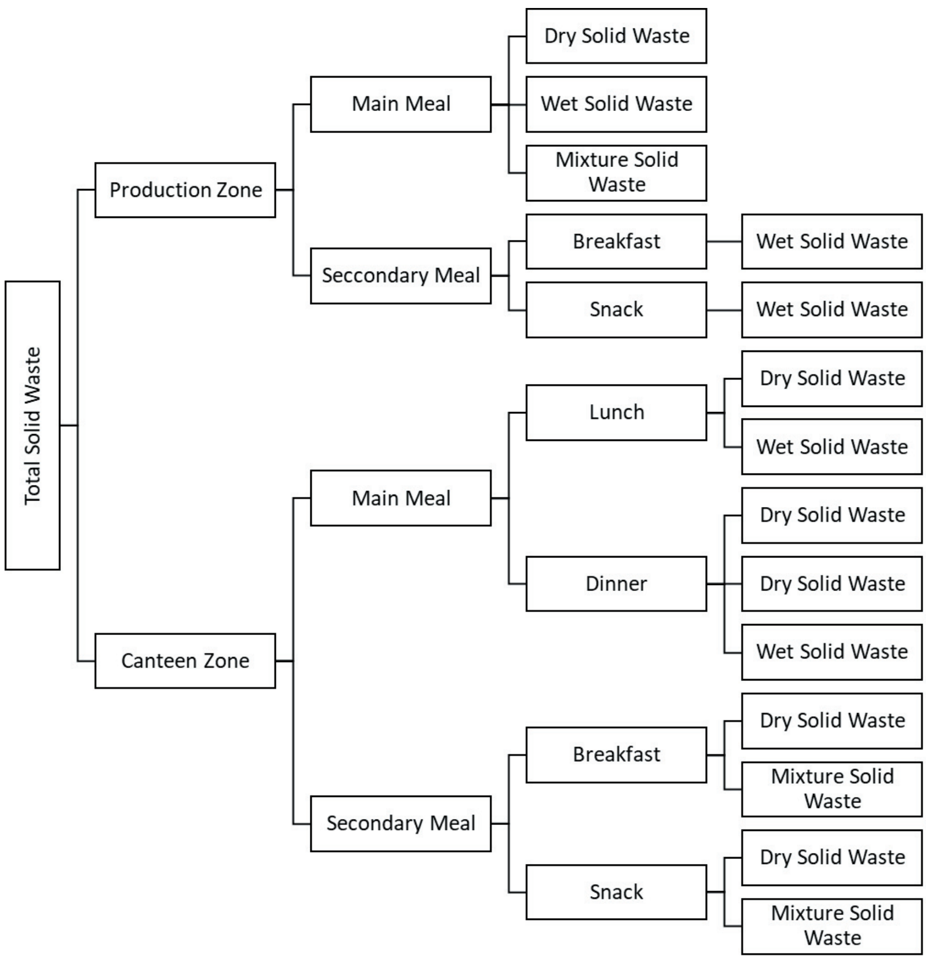

Figure 1. Solid waste generation flow, according to zones, categories and times.
Figura 1. Flujo de generación de residuos sólidos según zona, categoría y tiempo.

respectively. Regarding the time of generation, significant differences ($P<0.05$) were observed between the highest values found at the time of the main meals (0.14 and 0.15 kg/person, respectively, in PZ and CZ) and the lowest values observed with secondary meals (0.035 and 0.02 kg/person respectively in PZ and CZ, respectively). Figure 1 shows the diagram of the zones and moments of waste generation, identifying also by type of waste, and Table 1 presents the observed data corresponding to the diagram, with an average total mass of 802.41 (±220) kg/day of total SW.

During the processing and consumption of the main meal, made up of lunch and dinner, 92% of the total SW were generated and within this there are no significant differences ($P<0.05$) between the two zones (PZ=52% and CZ=48%); however, they differ in the type of waste generated. In PZ, a total of 355 kg SW/day were generated during the

Table 2. Chemical parameters measured at the WSW (n=3).
Tabla 2. Parámetros químicos de los WSW (n=3).

pH	TOC (%)	Nt	C/N	DM (%)	Hy	Li	Ce	HCe	Ash	Pre	aFDN	FDN
4.6-4.9	55.2-55.6	2.6-3.0	18.3-24.4	28.0-38.1	61.9-71.9	1.8-6.5	6.5-9.5	5.1-10.4	4.1-4.8	6.9-8.0	16.4-19.0	8.5-11.3

TOC: total organic. DM: dry matter. Hy: humidity. Li: lignine. Ce: cellulose. HCe: hemicellulose. Pre: proteine

main meal, where DSW=20%, WSW=55% and Mixture=25%. In CZ, during the main meal, 389 kg of SW/day were generated —83% of it was generated during lunch— and 91.2% was WSW, classified as FLW. The Mixture in the PZ was mainly composed of vegetable waste (e.g., leaves and peels of vegetables and fruits), meat scraps and raw fat, while in the CZ was processed food, with an average of 31% occupancy of the food tray. The total WSW was 587.7 kg/day and corresponded to the FLW. The DSW in PZ consisted of boxes, packaging, cans and bags, which originally contained the food, while in ZC there were disposable plastics such as expanded and rigid polystyrene and polypropylene, and to a lesser extent, paper (disposable napkins). The waste generated during the secondary meal was 59.87 kg/day, representing 7.4% of the total SW; 64.5% of it was generated in the PZ and consisted mainly of WSW obtained in the preparation of infusions (e.g., coffee and boiled yerba mate). In the ZC, 71% was DSW, consisting of the same types of waste as in the main meal.

In order to determine the most efficient destination of the residues, it is necessary, in addition to its identification, characterisation and quantification, to know its chemical composition. Table 2 shows the analytical data of the WSW, acid pH, high moisture content and C/N ratio. Another interesting aspect to identify the destiny of the residues is related to the lignocellulosic material, with the purpose of converting the lignocellulosic biomass into bioenergy; and the fiber fractions of the WSW, represented by %aFDN being components of plant cell wall: hemicellulose, cellulose, lignin, etc.; and the % ADF that represents a part of the cell wall composed, among others, of cellulose linked to lignin, an indirect indicator of the forage digestibility degree.

Discussion

The research questions were resolved by identifying, classifying, quantifying and knowing the quality of the waste generated, according to the established protocol. This allowed different management strategies to be weighted to the current final disposal in the landfill. The protocol made it possible to organise the fieldwork and to obtain the information necessary to quantify the generation. It was observed that 15% of the total SW corresponded to the dry fraction, of which 87% is generated in the main moment, either during the preparation in ZP and consumption in the canteen for lunch and dinner. This is not within the FLW fraction, and is of recyclable characteristics; so, the use of the 4R concept, waste management hierarchy and the Zero Waste based approach advocate waste prevention rather than waste treatment (Pandey et al. 2018). In this aspect, separation in the PZ would enable 70.75 kg of DSW/day to achieve the circular economy strategies. Many authors indicated the same type of dry waste of this work (i.e., mixed plastics and papers) is used to produce recycled solid raw materials and fuel as input for industries; thus, drive industries towards a more sustainable and environmentally friendly direction (Zhou et al. 2014). So, reuse and recycling not only has a direct impact on the economy in terms of total material consumption, but also eliminates the cost of proper waste disposal (Vargas et al. 2014). If we consider that source separation strategy is complied with in the PZ, it will also be possible to sustainably manage the 89.32 kg of Mixture, which represents 93.5% of the total Mixture generated between both zones, moving this waste to the DSW or WSW categories.

The concept of circular economy is more related in terms of reduction, reuse and recycling (de Oliveira et al. 2021). In addition to the pressure that should exist to promote these management practices related to the circular economy, feasible destinations were also analyzed considering their quality, which made it possible to identify the characteristics that influence the choice of the most efficient treatment or destination. Although incineration has been widely implemented as a technology to produce heat and then electricity from waste and simultaneously minimize its mass for final disposal or further treatment (Zhang et al. 2007), in this case, and due to the high % moisture and organic C, incineration is not advised because of the high energy cost. Although the annual contribution of food waste on environmental impact is low in Argentina (Skaf et al. 2021), due to the characteristics of WSW, direct disposal and incineration do not lead to transformation into resources or biogeochemical closure of elements.

Due to the characteristics of weak acidity, sufficient moisture and being rich in organic matter, biological transformation or bioconversion is feasible. Among the biological transformations, aerobic composting and/or anaerobic digestion are the most environmentally suitable treatments for processing household waste that can decompose (Soobhany 2018b), achieving maximum reprocessing of the waste (Walker et al. 2009), while other authors add that composting is more cost-effective and the final product more beneficial than anaerobic digestion for obtaining methane (Soobhany 2018a). Specifically, for kitchen waste, Gao et al. (2015) considered that it has great potential to produce methane through anaerobic digestion, stating that the efficiency of the process depended mainly on the degradation behavior of the substrate. Brancoli et al. (2021) argue that biofuel and digestate that are produced in the AD plants could be used as fuel for transport and fertilizer, respectively. This means that one can avoid using other fuels for transport (e.g., fossil fuel) and other types of fertilizers (e.g., synthetic fertilizers).

The % moisture of the WSW reached values of 71.95%, considered excessive for aerobic decomposition. According to Ramachandra et al. (2018), the main problem of biodegradable municipal waste is its high moisture content, which could generate greenhouse gases (mainly CO_2, CH_4, NH_3). Zhou et al. (2020) also observed that food waste from a university canteen in Zhejiang, China, had high initial moisture content, slightly higher than the optimal value (65%) for composting. Some authors propose acceptable ranges (e.g., % moisture content from 40 to 65% and pH between 5.5 and 9, and ideally between 6.5 and 8) (Rynk et al. 1992). There are pre-treatment techniques for solid organic wastes with high moisture content such as biodrying (with partial biodegradation of organic matter by aerobic microorganisms) or co-drying when various solid organic wastes are considered (Ma et al. 2016; Yuan et al. 2018). Regarding the C/N ratio, there are optimal ratios for each type of waste treatment, being in the studied WSW of 18.34-24.42, which were found to be within the range considered optimal for anaerobic digestion processes (Kumar and Samadder 2020), while they are at the lower limit of those considered ideal (initial C/N ratios of 25-30) for composting (Kumar et al. 2010). However, some researchers have successfully conducted composting with lower initial C/N ratios (Guo et al. 2012). The ashes % is relatively low; this feature may allow the incorporation of ashes from different local origins improving the circularity of the materials. Numerous examples of ash addition in the composting process are observed in the literature, with the advantages of improving mineralization and humic acid formation, reducing heavy metal lability, improving process aeration and increasing macro and micronutrient content (Koivula et al. 2004; Ravikumar et al. 2008; Wong et al. 2009; Punjwani et al. 2011). Lignin % is between acceptable and high values when close to 6.48%; in this situation, the composting process could be slowed down (Branzini and Zubillaga 2010). There are several alternatives to solve this problem; among them, various microbial inoculation alternatives are mentioned (Nakasaki et al. 2013; Song et al. 2018).

The use of lignocellulosic feedstocks, such as WSW, for the generation of novel cellulosic materials, energy generation by obtaining bioethanol or bio-oils has gained importance as it allows the circularity of waste, has a low cost and is available in large quantities (Li et al. 2010; Ganguli et al. 2020). According to several studies (Iqbal et al. 2013; Bilal et al. 2020), the percentage composition of lignocellulosic waste includes cellulose (10.5 to 60%), hemicellulose (0.20 to 42%) and lignin (8.2 to 48%). WSW possesses commensurate characteristics (Table 2) and can be put to these uses. In the case of ethanol production through the fermentation process, pH is a factor that generally defines the efficiency of this process; in this case, pH values were found within the range of 4.5 to 5.5, considered optimal (Moreno et al. 2019), and so, the production of bioalcohols. Furthermore, after cellulose, lignin is the second most abundant renewable source in nature and for this reason alternative uses have been developed to take advantage of this agroindustrial by-product, such as the generation of carbon fibers for the composite materials industry (Zhang et al. 2007).

The manufacture of animal feed is highlighted in literature as an alternative destination to digestion processes (Cai et al.

2015), managing to produce food additives or feed with a smaller environmental footprint compared to traditional alternatives of animal or vegetable origin (Matassa et al. 2016). According to Table 2, aFDN% were 16.4-18.97 and ADF% were 8.53-11.34. Regarding fiber quality, the concentration of aFDN in feeds correlates inversely with the concentration of energy and its chemical composition, so the amount to include in the formulation is a function of the energy requirements of the animals. aFDN % is an indicator of the level of feed digestibility, it includes cellulose and lignin as primary components in addition to variable amounts of ash and nitrogenous compounds (lignoproteins) (Hocking et al. 2004; Godoy et al. 2013).

Conclusions

The present study allowed the identification, classification, quantification and characterization of loss and waste of food and other residues during part of the food supply chain analyzed, comprised between the preparation and supply of food in the kitchen and canteen of the Río Santiago Shipyard, which provides food to more than 3000 persons/day. The protocol allowed organizing the field work and obtaining the necessary information to quantify the generation, contemplating the different zones and moments, being able to serve as a basis for future works that contemplate the problem of generations located according to sectors and moments. The generation of 802.4 kg of total waste/day was identified, representing 0.34 $kg.day^{-1}.person^{-1}$, with similar averages in the processing and canteen zones, of which 73% corresponds to wet waste. This identification allowed orienting strategies of waste management. The practices included in the 4R can be used for the management of waste identified as dry, generated mainly in the processing zone and during the preparation of the main menu. If the source separation strategy is complied with in said area, it will be possible to sustainably manage 89.32 kg of mixture, which represents 93.5% of the total mixture generated between both areas, transferring this waste to the DSW or WSW. The chemical characterization of the wet waste made it possible to select valorization criteria, highlighting bioconversion mechanisms, such as aerobic and anaerobic digestion, and its use in the formulation of animal feed, achieving with these strategies products with high added value. This work represents an opportunity for the search of strategies oriented to the sustainable management of waste, including food waste, pressured by a society that demands from public and private institutions the development of initiatives that contribute to achieve sustainable development in accordance with global strategies such as the ODS.

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