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Food waste quantification and investigation of risk factors for waste generation at street markets in Brazil

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Contents

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INTRODUCTION

Due to its effects on the economy, the environment, and societal issues such as food security, food waste has become an important global concern in recent decades. Food loss and waste are associated with a number of adverse environmental impacts, such as those caused by climate change and the contamination of terrestrial and marine ecosystems. According to Mbow et al. (2019), food loss and waste account for 8 percent of all anthropogenic greenhouse gas emissions, and 10 percent of the world's energy is used to produce food that is lost or wasted (FAO, 2017). To feed a population that is projected to reach 9.8 billion by 2050, food production must increase by 60 percent, which will exacerbate environmental stress (FAO et al., 2015).

The global concern has contributed to an increase in public debate on the subject, and a number of initiatives have been launched with the goal of preventing and valorising food waste. This is exemplified by the Sustainable Development Goals (SDGs) 12.3 target (United Nations, 2015) and the inclusion of food loss and waste in the Farm to Fork Strategy (European Commission, 2020), which aim to create a more equitable, healthier, and environmentally friendly food system.

This project, led by the Resource Management Group at the University of Borås, aimed to support the development of food waste prevention measures in Brazilian street markets through the quantification and characterization of waste and the identification of waste generation risk factors.

1. Summary of activities

1.1. WASTE COMPOSITIONAL ANALYSIS

The waste compositional analysis study was conducted over the course of one week in May 2022 in Ribeirão Preto. In February 2022, a preliminary study was conducted and data were collected regarding the number of street markets, their location, operating days, and number of stalls. In addition, relevant waste streams were identified, and information regarding waste collection, including collection schedule, disposal method, truck capacity, number of employees involved in collection, and presence of informal collection, was gathered. The study employed the methodology developed in a previous project funded by Naturvårdsverket (Brancoli, 2021). Sections 4 and 5 provide a detailed description of the waste quantification study.

1.2. COORDINATION WITH REGIONAL AGENTS

The local agents responsible for the administration, inspection, and waste management of the street markets were contacted, and an authorization agreement was signed in order to initiate the project. Local agents from the Ribeirão Preto Department of Infrastructure were briefed on the project and granted permission for its implementation. In addition to those responsible for the public authorities, the company in charge of waste management was also involved in the project in order to provide assistance during waste collection days. Other local agents participated in the project, including non-governmental organizations, waste cooperatives, and various levels of municipal administration.

1.3. TRAINING

Two courses were offered during the development of the project. The first course was aimed at the broad public, with the learning objective defined as ”Introduction to food waste and waste compositional analysis in street markets”. The second course, aimed at training the team responsible for developing the gravimetric analysis. Both courses were administered by Pedro Brancoli, Department of Resource Recovery and Building Technology, University of Borås.

1.4. DEFINITION AND PRIORITISATION OF FOOD PRODUCTS FOR THE RISK ANALYSIS

This study used the results from the waste quantification in Ribeirão Preto and the waste quantification from the previous Naturvårdsverket-funded project, ”Food waste quantification at street markets in the city of São Paulo”, to further characterise the waste at the product level in relation to its environmental impacts. The environmental impacts were quantified using the life cycle assessment methodology (LCA). LCA is a standardised methodology that aims to evaluate the environmental impacts associated with a product or service from cradle to grave (ISO, 2006a, ISO, 2006b).

The results of the various indicators were used to select food products for further study, i.e., those with a large amount of wasted mass, a high environmental impact, and nutrient loss. This information can also be used to guide decisions regarding food waste prevention and food security measures that will reduce their environmental impact, in addition to supporting the decision regarding the food waste fraction to be further investigated in relation to the risks for waste generation.

BOX 1: DISSEMINATION OF PROJECT RESULTS

PUBLICATIONS

Brancoli, P. 2021. Guide for waste composition analysis at Brazilian street markets. Borås, Sweden: University of Borås.

Brancoli, P., Makishi, F., Lima, P. G. & Rousta, K. 2022. Compositional Analysis of Street Market Food Waste in Brazil. Sustainability, 14, 7014.

Brancoli, P., Zisen, L., & Rousta, K. 2022. Waste quantification and environmental impacts of street markets' food waste in Brazil (Manuscript)

CONFERENCES

IV International Symposium on Agribusiness and Development (SIAD): Pedro Brancoli as a keynote speaker.

MEDIA

On numerous occasions, the research from this and previous projects funded by Naturvårdsverket has been presented to the media. It includes an interview done for G1, the largest news website in Brazil. The interview was conducted with Brazilian partners and aired on television. Examples of media appearances are provided below.

Figure 1. Interview for G1 - "Food waste at street markets"

Figure 2. UNESP Journal: "Food waste in street markets in São Paulo is the subject of a pioneering study at UNESP"

Figure 3. Saneamento Ambiental: "Research measures food waste at street markets in Sao Paulo"

2.

Project description

2.1. PROJECT GOALS

The primary aim of this project is to support food waste prevention in Brazilian street markets. The projects follow a framework for food waste reduction proposed by Eriksson (2015), which consists of the steps described below:

1. Quantification of waste
2. Hotspot identification
3. Analysis of causes
4. Implementation of measures
5. Evaluation of measures

The first step in the framework is the quantification of food waste. Food waste quantification is used to understand the quantities and the composition of the products being wasted. This information can be used for various purposes, such as to understand how much and where food waste occurs, to understand the reasons for waste generation, and to identify hotspots in the supply chain that should be prioritised for waste prevention measures.

Food waste quantification was performed in the previous project "Food waste quantification at street markets at the city of São Paulo" funded by Naturvårdsverket, which quantified and characterised food waste in street markets in the city of São Paulo, Brazil. The current project performed another food waste quantification in Ribeirão Preto, a mid-sized Brazilian city.

The primary goals of the second waste quantification round are first to validate the methodology developed in the previous project when it is applied in a different context, and secondly to investigate the waste generation and composition in a city with different demographic characteristics, considering that São Paulo is the biggest Brazilian city and the quantities and types of products wasted might be different for small or medium-sized cities or other regions in the country. In addition, the project intends to disseminate the developed methodology in order to assist municipalities with food waste quantification.

The second step in the framework refers to the analysis of the causes of waste generation. Food loss and waste occur for a variety of reasons at all stages of the supply chain, and identifying risk factors for food waste is critical for the development of food waste prevention and valorisation measures. The investigation of risk factors for waste generation is included as one of the goals of the project.

The information about the amount and composition of food waste collected in the previous project will be used to support the selection of relevant waste fractions to be further investigated in relation to risk factors for waste generation. The third step consists of the design of measures aimed at the prevention or valorisation of food waste. Finally, the fourth step consists in the evaluation of the measure in relation to criteria such as effectiveness, transferability and scalability, efficiency, and sustainability. The focus of this project was on the first and second steps of the methodology.

2.2. WASTE QUANTIFICATION

The project quantified and characterized food waste in street markets in Ribeirão Preto using the methodology proposed at Brancoli (2021). Ribeirão Preto is a Brazilian municipality located in the interior of the state of São Paulo, in the Southeast Region of the country. The city is situated about 315 kilometres from the state capital. It occupies an area of 650 000 km^2, of which around 20% is urban. The city has 720 000 inhabitants, making it the 27th most populous city in the country and the seventh in the São Paulo state, according to a population estimate calculated by the IBGE for 2021.

The goal of the waste quantification study is twofold: i) to validate the developed methodology previously described in Brancoli (2021) and ii) to investigate regional similarities and differences in relation to the quantity and composition of the food waste generated, contributing to a more precise estimation of street markets' food waste at the national level.

Public stakeholders were trained on the methodology for food waste quantification and characterization. The project used the training materials developed in the previous project for the training. The intended audience consisted of specialists in solid waste management, public servants, and universities. The participants had the opportunity to attend the lectures, participate in the training activities, and practise the methodology during the quantification activities. Furthermore, the project trained the waste quantification team on sampling techniques, measurement methods, safety procedures for working with waste, and the proper reporting of the waste quantification results. The quantification team consisted of members of a recycling cooperative from Ribeirão Preto. The collection and analysis of the food waste data are described in Section 5.

2.3. DEFINITION AND PRIORITISATION OF FOOD PRODUCTS FOR THE RISK ANALYSIS

There are different reasons for reducing food waste, e.g., reduction of environmental impacts, economic costs, and improvements in food security. Different food products may be prioritized in relation to the implementation of preventive measures based on the desired outcome. To achieve the highest benefits, it is crucial to identify food products whose reduction will lead to the highest savings in the intended outcomes. This study combined the gravimetric results for Ribeirão Preto and São Paulo and further characterized waste at the product level in terms of its environmental impacts.

The environmental impacts were quantified using the life cycle assessment methodology (LCA). LCA is a standardised methodology that aims to evaluate the environmental impacts associated with a product or service from cradle-to-grave (ISO, 2006a, ISO, 2006b).

The economic costs and nutrient loss will be calculated considering individual product characteristics. The loss of calories, and micro- and macronutrients will be estimated using information regarding the complete nutrient profiles of food products.

The results of the mass quantification and environmental assessment will be combined with other indicators on a future project, such as loss of nutritional value and economic cost, to select food products for further investigation in relation to the causes of food waste, i.e., food products with a large mass of wasted food, a high environmental impact, and nutrient loss. Besides supporting the decision on the food waste fraction to be further investigated in relation to the risks for waste generation, this information can also be used to guide decisions on food waste prevention and food security measures that will lead to fewer nutrient losses and reduce their environmental impact.

2.4. ANALYSIS OF RISK FACTORS FOR FOOD WASTE

The results from the food waste quantifications performed in São Paulo's and Ribeirão Preto street markets provided valuable information on food products that are wasted in large amounts. This information was combined with the environmental indicators to support the selection of products to be prioritised for the investigation of the causes and risk factors for waste generation.

It included a literature review on risk factors for waste generation and interviews with different actors along the supply chain, including producers, vendors, wholesalers, and other relevant actors in the supply chain. The goal of this qualitative study is to investigate risk factors for waste generation in distribution, storage, and selling practices.

3.

Methodology

3.1. CHARACTERIZATION OF THE STREET MARKETS

The street markets investigated were pre-selected observing aspects related to the number of stalls and location. To collect information, direct observation techniques were used and applied to the study of spatiality and layout of the street markets and urban occupation of the surroundings.

A criterion was established for selecting street markets with more than 10 stalls. The goal was to avoid unrepresentative data and for better use of human resources and capital since it would only be possible to quantify one street market per day. Nevertheless, according to the municipal register, the occurrence of street markets with fewer than 10 stalls are uncommon in Ribeirão Preto. Regarding the location, information regarding the urban occupation of the area surrounding the street markets and the average income of the population was gathered.

Regarding the urban occupation, the need for a heterogeneous sample was considered. Although a significant number of the street markets selected were concentrated in central areas of the city, the sample was comprised of street markets that took place in residential and commercial neighbourhoods, with predominantly horizontal (houses) or predominantly vertical (apartment buildings) occupation. The initial screening was conducted using Google Street View, and the characterization was confirmed through on-site inspections.

Due to the lack of more robust and complex socioeconomic indicators at the neighbourhood level for the city of Ribeirão Preto, such as the HDI used in the survey conducted in São Paulo in 2021, the average income was used as a descriptive variable.

3.2. INTERVIEWS

Vendors were interviewed using a semi-structured format in order to collect additional information regarding the organizational structure and management of street markets. Each interview lasted between 15 and 20 minutes, totalling more than a thousand hours of interviews.

The Municipal Department of Finance lists 216 street market vendors in its register of companies. Considering that all vendors in the registers are active, the sample of the interviews would represent approximately one third of the total vendors. However, both the team's field investigation and the vendors' reports indicate that the number of active vendors is significantly lower than the number registered with City Hall.

In the interviews, qualitative and quantitative demographic information were collected regarding the age of the vendor, how many years they have worked in street markets, the frequency with which he/she participates in street markets (days per week), and their relationship with the stall (owner, employee, or other). Furthermore, data was gathered related to the estimated number of consumers during the day, products sold at the stall, the origin of the products, the reasons for purchasing and selling specific products, the relationship with suppliers, and the frequency of supply.

The interviews also investigated the relationship with customers, the ability to forecast demand, strategies adopted to avoid food waste, the destination of waste, the perception of the decrease in public, the perception of the reasons for the decrease in the number of consumers, whether other forms of commercialization are adopted, and alternative commercialization channels adopted. Finally, the existence of bonds of collaboration and reciprocity between street markets, and formal rules and supervision were explored. Part of the data was tabulated in an Excel spreadsheet with a view to its treatment and future analysis. The database also contains the researchers' observations and photographic documentation.

3.3. WASTE QUANTIFICATION

This study used a classification system developed in (Brancoli et al., 2022). The description of the methodology was extracted verbatim from the open access published article (Box 2).

BOX 2: WASTE FRACTIONS

“A classification system for food waste with 3 levels of subcategories was developed (Table 1). The basic idea is to increase the comparability of the results. Furthermore, this approach enables a classification that is useful for the goals of this compositional analysis and allowed the highest level of disaggregation, taking into account practical limitations on the number of fractions analysed in a compositional analysis.

Level 0 comprises packaging waste, and avoidable and unavoidable food waste. Packaging waste refers to wholesale packaging materials or those used for the transportation of the products. Food waste is defined accordingly to UNEP (2021), as food and the associated inedible parts removed from the human food supply chain and sent to landfill, controlled combustion, sewer, anaerobic digestion, composting or land application. Avoidable food waste are products that were edible at some point in time before being discarded. Unavoidable food waste refers to parts of the products that are typically not consumed by people, such as peels. The definition of food waste into avoidable and unavoidable has been reported in several publications (e.g. Quested et al., 2013, Bernstad Saraiva Schott and Andersson, 2015). Several relevant publications, such as the Food Waste Index (UNEP, 2021) and the FUSIONS definitional framework for food waste recommends the disaggregation of food waste into avoidable and unavoidable, as a key factor for the development of policies and the application of the waste hierarchy (Östergren et al., 2014).

Level I further differentiate the avoidable fraction into six food group categories: (i) leaves, flowers and stems, (ii) processed products, (iii) tubers, bulbs and roots, (iv) vegetables, (v) fruits and (vi) meat. Definitions of the terms ‘fruits’ and ‘vegetables’ are not universally shared and their classification varies in the literature depending on the goal of the study. For example, WRAP (2009) defines household food waste into 13 groups and differs fruits and vegetables into three categories: fruits, salads and vegetables. In the literature of dietary guidance, Pennington and Fisher (2009) proposed a classification of food in ten different categories, which includes for example dark green leaves, legumes and citrus family fruits.

Fruits are botanically defined, but there is no botanical definition of vegetables and their classification is influenced by cultural norms, such as their culinary use (Thompson et al., 2011). The culinary definition of vegetables includes leaves, flowers, stems, tubers, bulbs, seeds and fruits (see Table 1 for examples). Vegetables are normally consumed in dishes or as savoury appetizers. Even though fruits are botanically defined as the seeds and surrounding tissues of a plant, fruits are customarily also defined by their culinary use, and are referred to as the pulpy structures of produces that are typically sweet or sour, and are normally consumed as snacks and dessert (Pennington and Fisher, 2009).

In this study, the most common culinary use was applied for food items that could be classified into several food category groups. For instance, avocados are often defined as vegetables in the North American and European literature, due to their common use in savoury recipes and salads (Pennington and Fisher, 2009). However, in Brazil avocados are mainly consumed as a fruit and were defined as so. A category was defined for processed products, which includes fruits and vegetables that are washed, peeled, cut or minced and sold in packages, typically in plastic trays. The inclusion of this category was justified by large quantities observed being sold during the pre-study and the increase in sales of such products in Brazilian retail (de Brito Nogueira et al., 2020).

Level II categorize the food groups at the product level (Table 1). The unavoidable food waste category was disaggregated into three products, namely peels, sugarcane bagasse, a by-product derived from the production of sugarcane juice (caldo de cana), a typical beverage, and coconut waste, which is produced after the extraction of the water, another common beverage sold in Brazilian street markets. When a product was wasted entirely, it was classified entirely as avoidable, e.g. a wasted banana was weighted with the peel and categorized as an avoidable product. Products at level II were selected following three criteria. First, products that were observed large amounts of waste during the pre-study, secondly based on the Brazilian consumption profile of fruits and vegetables (IBGE, 2020) and finally due to relevance for waste management operators, e.g. packaging, meat, coconut and sugarcane bagasse.

The 'external waste' fraction refers to materials that were not generated by the street market but were collected together (see Section 2.3 for the waste sampling description). Examples of 'external waste' were diapers, household waste and construction material. Although this fraction is not part of the street market, it is presented in Table 3 taking into account that it can be relevant to waste management operators, since it can contaminate the organic waste flow to be sent to composting."

Table 1. Waste category levels, extracted from Brancoli et al. (2022).

Level 0	Level I	Level II	Description
Packaging	Packaging	Packaging	Plastic, wood, straw, paper and cardboard.
Avoidable food waste	Leaves, flowers and stems	Broccoli and Cauliflower	
		Cabbage	
		Other	E.g. lettuce, spinach, parsley, coriander, and stems.
	Processed products	Tubers, bulbs and roots	Products that are processed, e.g. peeled and cut, and are often sold in plastic trays.
		Fruits and vegetables	
		Leaves, flowers and stems	
	Tubers, bulbs and roots	Potato	
		Carrot	
		Onion	
		Other	e.g. garlic, beet, yam, cassava, turnip, and radish
	Vegetables	Tomato	It includes botanically classified fruits that are culinarily classified as vegetables, and seeds.
		Pumpkin	
		Bell pepper	
		Chayote	
		Other	E.g. e.g. zucchini, eggplant, cucumber, peppers, okra.
	Fruits	Banana	
		Orange	
		Watermelon	
		Papaya	
		Other	E.g. avocado, pineapple, peach, kiwi, lemon, mango, melon, strawberry.
	Meat	Meat	Beef, pork, chicken, seafood, etc.
Unavoidable food waste	Unavoidable food waste	Coconut	
		Sugarcane bagasse	
		Peels	
External waste	External waste	External waste	Fractions that are not produced in the street market, but are collected together.

3.4. LIFE CYCLE ANALYSIS

3.4.1. GOAL AND SCOPE DEFINITION

This study's objective is to evaluate the environmental impact of various food waste products in order to estimate the environmental impacts of food waste in São Paulo and Ribeirão Preto and to identify the system's hotspots, i.e., the processes and activities that contribute significantly to the total environmental impact. The results are expected to support both the examination of underlying causes for food waste and the development of possible solutions for food waste prevention and valorisation.

The functional unit (FU) was defined as the amount of waste produced per stall in the street markets investigated. Food waste is defined as food that has been removed from the human food supply chain along with any associated inedible components and delivered to landfill, controlled combustion, sewage, anaerobic digestion, composting, or land application (Zhongming et al. 2021).

3.4.2. SYSTEM BOUNDARIES

The system boundary in the study is from cradle to grave. Therefore, it includes all processes from primary production to waste management (Figure 4).

The production of agricultural products included land use, seedlings, fertiliser, pesticides, machinery work, electricity, irrigation, transportation, cooling during transportation, water washing, and other processes, such as packaging of fertiliser and pesticide. Figure 5 depicts the various steps involved in the production of meat, including animal husbandry, slaughter, electricity consumption, transportation, and water washing.

3.4.3. LIFE CYCLE INVENTORY ANALYSIS

The entire life cycle of the selected products, consisting of four steps: production, transportation, street market sales, and disposal, was modelled using the software SimaPro. The processes involved in agricultural production range from seed production to harvesting. Figure 5 provides additional details. There are six categories of avoidable food waste in fractions level I: leaves, flowers and stems, processed products, tubers, bulbs and roots, vegetables, fruits, and meat. These six categories are further subdivided into 26 different products in fractions Level II (Table 1).

Fertilisers are a significant contributor to the environmental impacts of agricultural production, and their dosage varies by region. In order to ensure the accuracy of this study, all inventoried fertilisers in this study were adapted from EcoInvent global dataset to the local conditions based on published literature or official websites. Other inventoried processes such as irrigation, seedling production, electricity, machinery work, etc., were investigated and adjusted to conform to typical agricultural production practices in Brazil. The remaining data for agricultural production are derived from the Ecoinvent database of global average models (Wernet et al., 2016). Since no differentiation was made during the waste compositional analysis, meat was modelled as consisting of three types of meat: pork, beef, and chicken.

The category of unavoidable food waste consists of four products: peels; sugarcane bagasse, a by-product of sugarcane juice production; corn straw; and coconut shells, a by-product of the extraction of coconut water, a common beverage sold on Brazilian street markets (Brancoli et al., 2022). Since all the unavoidable food waste is grown alongside edible elements for a specific purpose, the edible part has already been consumed and the agriculture production is therefore excluded. Landfill was modelled as the final destination for organic waste.

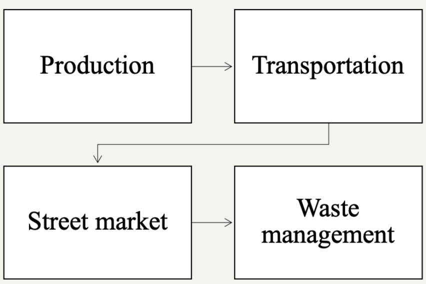


Figure 4 (above). Simplified flowchart process for street market product.

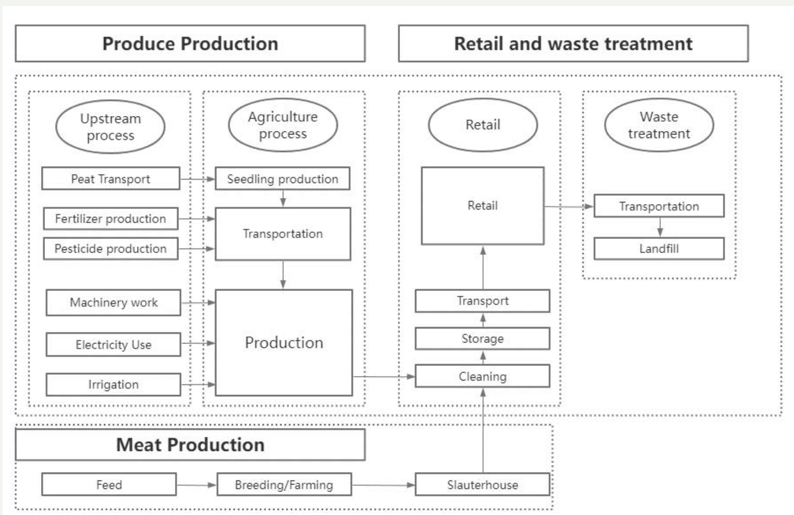


Figure 5 (right). System boundaries for cradle-to-grave fruit and vegetable production.

4.

Waste quantification

4.1. DESCRIPTION OF THE STREET MARKETS IN RIBEIRÃO PRETO

Data from the municipal government suggests the existence of five daily street markets, each one operating in different parts of the city, simultaneously, from Tuesday to Sunday. Since the COVID-19 pandemic, at least 40 percent of these street markets have ceased operations or significantly shrunk in size, according to the exploratory investigation.

The Municipal Department of Finance lists 216 street market vendors in its register of companies. Considering that all vendors in the registers are active, the sample of the interviews would represent approximately 30% of the total market vendors. However, both the team's previous field study and the vendors' reports indicate that the number of active vendors is significantly lower than the number registered with the city hall.

Ribeirão Preto's street markets are distinguished by the wide variety of goods offered for sale at their stalls. In the post-pandemic era, the diversification strategy adopted by some vendors appears to be an action against contingencies. The offer of multiple products seems to be a way to ensure a greater probability of purchase by customers. The idea is that by offering a greater variety of items, the possibility for the customer to buy something increases. This strategy, almost dominant among the vendors of Ribeirão Preto, is only made possible by the flexibility of inspection since the stall is only allowed to sell one type of product.

The street markets included in the waste quantification are described in Table 2 in relation to their address, the urban occupation characteristics of the neighbourhood, and the estimated household income. Due to the lack of robust and complex socioeconomic indicators at the neighbourhood level for the city, the average income was used as a descriptive variable.

4.1.1. STREET MARKET AT RUA COMANDANTE MARCONDES SALGADO

The street market occurs on Tuesdays, from 7:00 AM to 12:00 PM. Its 55 stalls occupy approximately 350 meters of Comandante Marcondes Salgado Street between Bernardino de Campos and Prudente de Morais streets. It was observed a consumer density of 0.6 people/m^2 at the time with the largest public.

The characterization of the stalls according to their main selling product revealed: 1 stall selling clothes, 1 stall selling beverages (sugarcane juice and coconut water), 13 fruit stalls, 17 vegetable and fruit stalls, 3 egg stalls, 2 household utility stalls (household and kitchen utensils and appliances), 2 stalls selling bakery products, 1 stall selling poultry, 1 stall selling cheese, 1 stall for processed fruits and vegetables, 3 stalls of pamonha (a typical Brazilian corn dish) and 2 stalls of pastel (typical fried pastry dish).

4.1.2. STREET MARKET AT RUA OLAVO BILAC

The street market takes place on Wednesdays from 7:00 AM to 12:00 PM. Its 25 stalls occupy a portion of Olavo Bilac Street extending approximately 180 meters between Prudente de Morais and Rui Barbosa streets. It was observed a consumer density of 0.3 people/m^2 at the time with the largest public.

The characterization of the stalls according to their main selling product revealed: 1 stall selling beverages (sugarcane juice and coconut water), 6 fruit stalls, 8 vegetable and fruit stalls, 2 egg stalls, 1 household utility stall (household and kitchen utensils and appliances), 1 stall selling bakery products, 1 stall selling poultry, 2 stalls of pamonha and 2 stalls of pastel.

4.1.3. STREET MARKET AT RUA TERESA CRISTINA

The street market is held every Thursday from 7:00 AM until 12:00 PM. Its 38 stalls occupy approximately 300 meters of Teresa Cristina Street between Washington Luiz and Princesa Isabel streets. It was observed a consumer density of 0.3 people/m^2 at the time with the largest public.

Code	Name	Street Address	Estimated household income (USD)	Urban Occupation
SM-RB 1	Marcondes Salgado	Rua Comandante Marcondes Salgado. Centro.	2700 - 4100	Commercial buildings and vertical condominiums
SM-RB 2	Rua Olavo Bilac	Rua Olavo Bilac. Vila Seixas.	3100 - 4100	Commercial buildings and offices
SM-RB 3	Rua Teresa Cristina	Rua Teresa Cristina. Jardim Paulistano.	400 - 2000	Residential district with houses (horizontal)
SM-RB 4	R. Franca	Rua Franca. Jardim Paulista.	400 - 2000	Residential district with houses (horizontal)
SM-RB 5	R. Cap. Osório Junqueira	Rua Teresa Cristina. Jardim Paulistano	400 - 2000	Commercial buildings and vertical condominiums
SM-RB 6	Av. Portugal	Rua Franca. Jardim Paulista	3100 - 4100	Commercial buildings and vertical condominiums

Table 2. Selected street markets, average income and urban occupation.

The characterization of the stalls according to their main selling product revealed: 2 stalls selling clothes, 2 stalls selling beverages (sugarcane juice and coconut water), 10 fruit stalls, 11 vegetable and fruit stalls, 2 egg stalls, 2 household utility stalls (household and kitchen utensils and appliances), 2 stalls selling bakery products, 1 stall selling cheese, 2 stalls of pamonha 3 stalls of pastel (typical fried pastry dish) and 1 stall selling spices.

4.1.4. STREET MARKET AT RUA FRANCA

The street market occurs on Fridays, from 7:00 AM to 12:00 PM. Its 41 stalls occupy approximately 250 meters of Franca Street between Itapura Street and half of the block between Cesário Mota and Laguna Streets. It was observed a consumer density of 0.4 people/m^2 at the time with the largest public.

The characterization of the stalls according to their main selling product revealed: 2 stalls selling beverages (sugarcane juice and coconut water), 8 fruit stalls, 10 vegetable and fruit stalls, 3 egg stalls, 2 household utility stalls (household and kitchen utensils and appliances), 3 stalls selling bakery products, 1 stall selling poultry, 2 stalls selling cheese, 1 stall for processed fruits and vegetables, 3 stalls of pamonha, 4 stalls of pastel and 1 stall selling spices.

4.1.5. STREET MARKET AT RUA CAPITÃO OSÓRIO JUNQUEIRA

The street market occurs on Saturdays, from 7:00 am to 1:00 pm. Its 19 stalls occupy approximately 140 meters of Capitão Osório Junqueira Street between Aristides de Oliveira Street and Orlando Augusto do Nascimento square. It was observed a consumer density of 0.2 people/m^2 at the time with the largest public.

The characterization of the stalls according to their main selling product revealed: 3 fruit stalls, 4 vegetable and fruit stalls, 1 egg stall, 1 household utility stall (household and kitchen utensils and appliances), 1 stall selling bakery products, 1 stall selling poultry, 1 stall selling cheese, 1 stall of pamonha, 3 stalls of pastel and 1 stall selling industrialized sweets.

4.1.6. STREET MARKET AT AVENIDA PORTUGAL

The street market is held on Sundays from 7:00 AM to 2:00 PM. Its 68 stalls occupy approximately 350 meters of the street between the Agnel Rossi Square and the Candido Portinari Street. It was observed a consumer density of 1.7 people/m^2 at the time with the largest public.

The characterization of the stalls according to their main selling product revealed: 2 stalls selling clothes, 3 stalls selling beverages (sugarcane juice and coconut water), 15 fruit stalls, 17 vegetable and fruit stalls, 2 egg stalls, 2 household utility stalls (household and kitchen utensils and appliances), 4 stalls selling bakery products, 2 stalls selling meat products, 3 stalls selling cheese and sausage, 2 stalls for processed fruits and vegetables, 6 stalls of pamonha, 6 stalls of pastel 2 stall selling spices, 2 stalls selling flowers and 1 stall selling industrialized sweets.

4.2. VENDORS

The study interviewed 59 vendors, and among them, 86% are owners of the stall. The average age is 53 years, with a maximum of 72 years and a minimum of 21 years. The average experience time working in the street market is 27.5 years, and many of the vendors have more than 40 years of experience.

Most respondents are male (71%). In many cases, the activity is transmitted through family relationships, but some have purchased the stall and the right to sell on street markets from former employers and through a purchase and sale contract. Some information gathered during the interviews suggests that the average price per square meter ranges from R$ 1,500 to R$ 2,000, although this cannot be determined with precision.

The number of weekly street markets in which each vendor participates ranges between one and six. On average, the vendors interviewed attend 4.3 street markets per week. The frequency of operation of the stalls is directly related to the supply strategies adopted, although other factors such as the availability of labour and the target audience also influence the decision. There is a trend for vendor-producers, i.e., those who produce the majority of the sold goods, to attend fewer street markets per week.

The individual trajectory of vendors is diverse. Some have inherited the activity from their parents and close relatives—a recurring aspect among older and more experienced vendors—but some have left other work and income for the market activity.

4.3. SUPPLIERS

Preliminary findings indicate a close connection between purchasing practices, individual sales strategies, and the generation of food waste at street markets. For the stalls in the investigated street markets, four distinct suppliers were observed: two wholesalers (CEASINHA and CEAGESP), own production, and other suppliers.

The CEASINHA, or CEASA Centro, is located in the old facilities of a public wholesaler on Av. Bandeirantes. It is administered by a regional association of agricultural producers (Associação dos Produtores de Hortifrutigranjeiros de Ribeirão Preto e Região) which consists primarily of local producers, mostly on a small scale.

CEAGESP (Companhia de Entrepostos e Armazéns Gerais de São Paulo) is a federally owned corporation that operates under the direction of the Ministry of Agriculture, Livestock, and Food Supply. The CEAGESP in Ribeirão Preto handles approximately 240 thousand tons of food annually, making it the largest wholesaler in the interior of the state of São Paulo, accounting for 5.6% of the CEAGESP network. The origins of the products vary, with the majority of them coming from distant locales and some from outside the country.

Own production is associated with more specific products, mainly organic produce. Production takes place in cities close to Ribeirão Preto, within a radius of up to 50 km. The vendors frequently also sell goods from nearby neighbours, other small businesses, and wholesalers, among other suppliers.

The fourth form of supply is characterised by informal relationships, largely based on relational contracts and ties of reputation and trust. The suppliers are resellers, transporters, and distributors of agricultural products. The products in this case are a little more specific to the products purchased at CEASINHA and CEAGESP, closely linked to aspects of standardisation and perceived superior quality.

In order to enable their diversification, quality, and pricing strategies, the vendors frequently combine one or more supply types. Vendors seeking product differentiation are frequently vertically integrated or sourced from reputable suppliers. In some cases, the acquisition of products at CEASINHA enables product diversification strategies without giving up a certain quality (harvest time, size, colour and maturation). In the case of CEAGESP, supply is more linked to low-price strategies adopted by the stalls.

In general, the strategy of diversifying the products sold seems to have an immediate reducing effect on food waste at street markets. The quantities purchased are smaller, which reduces the amount of waste. It is customary to sell surplus products at upcoming street markets. In the case of own products, the extended shelf life – as it is a fresher product – allows for commercialization to other street markets or businesses in the region. In the case of products from CEAGESP, the shelf life is much shorter, on average, two days. At the end of the second day of exposure, prices drop and products are sold off. When leftovers still occur, they are donated or discarded.

4.4. WASTE MANAGEMENT

The preliminary findings of this study support earlier work done in São Paulo and demonstrate that the street markets are an open socio-spatial system with significant interactions with its surroundings. For instance, the local dynamics reveals innovative solutions for the management of the waste generated at the street markets by utilising it for animal feed. This was observed for different waste fractions, but particularly for corn husks (Figure 7). In comparison to São

Figure 6 - Street market Av. Portugal.

Figure 7 - Informal waste collection of corn straw.

Paulo, a higher volume of organic waste was collected for use as animal feed in Ribeirão Preto. In contrast, a higher volume of packaging collectors, particularly cardboard, was observed in São Paulo.

4.5. RIBEIRÃO PRETO

4.5.1. COORDINATION WITH REGIONAL AGENTS

The local agents responsible for the administration, inspection and waste management of the street markets were contacted and an authorization term was signed so that the project could be developed. The project was presented to local representatives from the Ribeirão Preto Infrastructure Department, and permission was given for it to be carried out. In addition to those responsible for the public authorities, the company responsible for the waste management was involved in the project, in order to assist in the days of waste collection.

A second level of alignment with local agents took place by the invitation and dissemination of the free and introductory course on food waste quantification techniques. The course was publicised through a formal communication sent to the following institutions:

Instituto de Estudos Avançados, Universidade de São Paulo. Institute of Advanced Studies, University of São Paulo.

Secretaria de Infraestrutura de Ribeirão Preto. Secretariat of Infrastructure.

Secretaria de Meio Ambiente de Ribeirão Preto. Secretariat of Environment.

Secretaria da Inovação e Desenvolvimento de Ribeirão Preto. Secretariat of Innovation and Development.

Secretaria de Assistência Social de Ribeirão Preto. Secretariat of Social Assistance.

Secretaria da Saúde de Ribeirão Preto. Secretariat of Health.

Secretaria de Educação de Ribeirão Preto. Secretariat of Education.

Conselho Municipal de Segurança Alimentar e Nutricional - COMSEAN - Ribeirão Preto. Municipal Food and Nutritional Security Council.

Guarda Civil Metropolitana de Ribeirão Preto (Patrulha Ambiental). Metropolitan Civil Guard of Ribeirão Preto (Environmental Patrol). Mesa Diretora da Câmara Municipal. Board of Directors of the City Council

PROCON. Agency for protection of the rights and interests of consumers.

Cooperativa Organica Agroflorestal "Comuna da Terra" Casa das Mangueiras. Organic Agroforestry Cooperative.

4.5.2. TRAINING

Two courses were offered during the development of the project. The first course was aimed at the broad public, with the learning objective defined as "introductory literacy on food waste and waste quantification in street markets". The second course is aimed at training the team responsible for developing the gravimetric analysis.

The course aimed at the general public was administered by Pedro Brancoli, Department of Resource Recovery and Building Technology - University of Borås, Sweden. The title of the course was "Introduction to the quantification of food waste in street markets". The main objective was to present the methodology of quantification of food waste with a focus on street markets. There were a total of 137 people from various backgrounds enrolled in the course (Figure 8).

BOX 3: TRAINING MODULES

SAFETY AND THEORY

The lecture discusses hygiene standards, risks (such as diseases, sharp or pointed objects, and allergies), and aspects of safety (such as equipment and behaviour). The theory underlying characterization studies and its application as a research tool are discussed in the lecture. Moreover, this lecture also describes the goal and scope of the current project.

WASTE COLLECTION

The lecture's main emphasis is on the methodological and practical aspects of waste collection, including equipment, permits, the responsibilities of each staff member, the layout of the working area, protocol, and an equipment checklist.

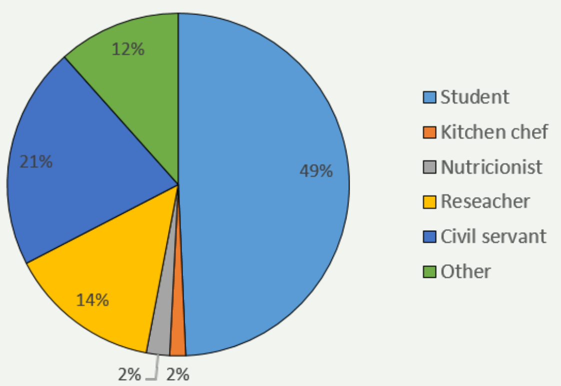
SORTING

The lecture describes the protocol for food waste sorting, including sorting site preparation, the methodology for food waste characterization, the routine for sampling, sorting, weighting and disposal, and how to fill the protocol. Furthermore, it discusses safety aspects during the sorting and sampling.

ANALYSIS OF RESULTS

The lecture is focused on the statistical analysis and interpretation of the data generated. It also includes calculation procedures, such as correction factor and source of errors.

Figure 8. Overview of course participants.



5. Compositional analysis results

5.1. RIBEIRÃO PRETO

The results from the waste compositional analysis in Ribeirão Preto reveal that the amount of avoidable food waste produced in each stall ranged from 1.24 to 6.9 kg (Figure 9). The analysis of waste at Level 0 revealed that avoidable waste contributed the least to the total waste in all analysed street markets, with an average contribution of approximately 20%. Packaging had the largest share of total waste, varying from 22 to 62% in RB6 and RB5, respectively. Around 35% of the total waste in the street markets analysed consisted of unavoidable food waste, the equivalent of 3.2 kg per stall (Figure 9).

Figure 11 displays the same results as Figure 9, but the results are disaggregated to Level I. The group of avoidable food waste with the largest average waste generation was fruits and leaves, flowers, and stems (Figure 10). Particularly large quantities of single leaves and oranges were observed on the street markets.

Leaves, flowers, and stems were the primary sources of avoidable food waste in street markets RB1 and RB5, whereas RB2 and RB3 generated large amounts of fruit waste (Figure 11). Similar to what was observed in São Paulo, leafy products were especially susceptible to damage from water loss, chlorophyll degradation, mechanical damage, and fungal or bacterial decay (Lana and Moitt, 2020).

The majority of fruit waste from RB1 and RB2 was oranges, whereas RB5 produced a substantial amount of papaya. For the street market RB6, 70% of the waste in the fruit category was comprised of other products (Table 3). In the vegetable category, the loss rate per stall ranged from 0.1 to 1.5 kg on SM 1 and SM 4, respectively, with an average of 0.6 kg lost per stall. Similar to the findings of Santos et al. (2020) and Brancoli (2021), tomato was the product with the largest wastage in the category.

Figure 10. Waste of sugarcane bagasse and leafy products in Ribeirão Preto's street markets.

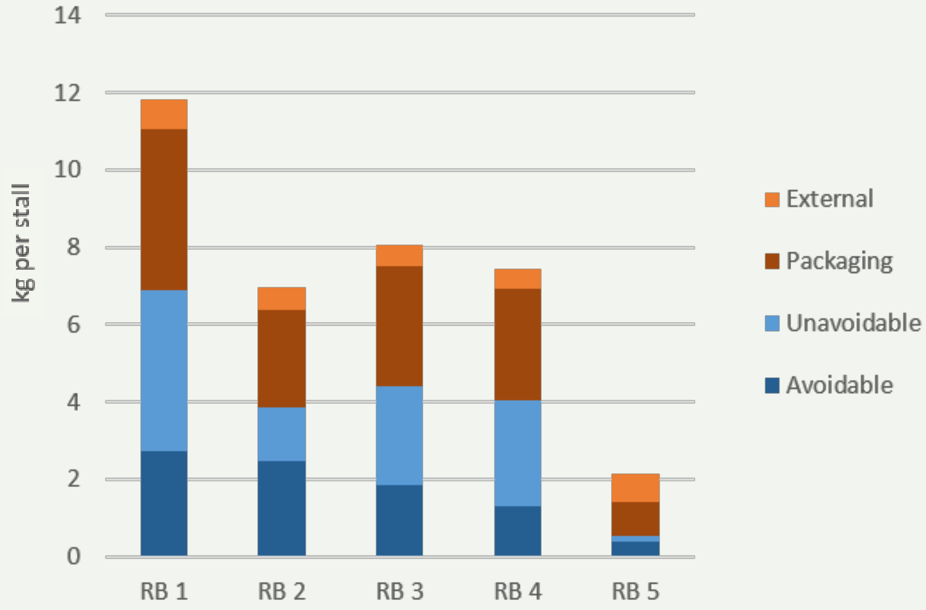


Figure 9. Waste generation per stall at Ribeirão Preto's street markets (Level 0)

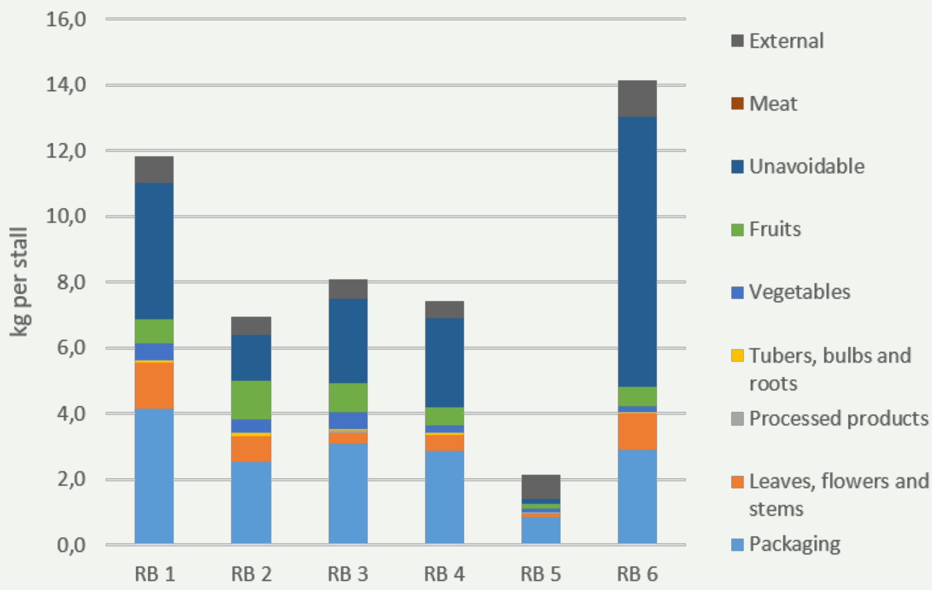


Figure 11. Waste generation per stall at Ribeirão Preto's street markets (Level I).

Table 3. Waste composition of food waste from Ribeirão Preto (RP) and São Paulo (SP) street markets (kg/street market).

Level 0	Level I	Level II	RB 1	RB 2	RB 3	RB 4	RB 5	RB 6	SP 1	SP 2	SP 3	SP 4
Packaging	Packaging	Packaging	228.3	63.5	117.3	117.4	16.3	198.3	8.0	224.3	136.0	229.6
Avoidable	Leaves, flowers and stems	Broccoli and Cauliflower	0.8	0.1	0.1	0.5	0.0	1.3	0.0	0.0	1.4	6.5
		Cabbage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
		Other leaves, flowers and stems	76.1	19.4	12.6	19.3	1.9	71.6	0.0	85.8	272.1	294.4
	Processed products	Processed tubers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
		Processed fruits and vegetables	0.0	0.1	2.0	0.5	0.0	0.7	0.0	0.0	0.0	0.0
		Processed leaves, flowers and stems	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.1
	Tubers, bulbs and roots	Potato	1.8	0.4	0.4	0.6	0.0	0.8	0.0	1.2	0.9	13.9
		Carrot	0.0	0.1	0.4	0.0	0.0	0.5	0.0	0.0	0.8	2.8
		Onion	0.8	0.7	0.6	0.3	0.0	0.6	0.0	0.2	1.8	10.0
		Other tubers, bulbs and roots	1.5	1.2	0.4	1.2	0.0	0.9	0.0	0.0	0.2	6.4
	Vegetables	Tomato	6.9	1.2	9.3	1.8	1.0	2.5	0.5	3.7	9.7	47.8
		Pumpkin	3.2	0.3	1.4	0.2	0.0	0.9	0.0	2.0	0.0	0.8
		Bell pepper	0.2	0.4	0.7	0.9	0.0	0.4	0.0	0.0	0.2	0.0
		Chayote	1.3	1.7	0.0	0.6	0.0	0.4	0.0	0.0	0.0	0.0
		Other vegetables	16.8	6.8	7.9	6.1	0.9	8.0	0.0	24.3	4.1	11.2
	Fruits	Banana	1.6	2.2	4.2	0.5	0.0	1.6	0.0	0.8	15.9	8.7
		Orange	22.2	14.4	5.5	7.5	1.1	6.2	0.0	13.8	9.4	20.7
		Watermelon	0.0	0.0	0.0	3.6	0.0	2.8	0.0	0.7	8.7	0.0
		Papaya	3.5	1.7	4.0	2.8	1.5	2.9	0.0	2.1	3.6	2.8
		Other fruits	12.3	11.1	20.9	7.3	0.1	26.3	0.0	8.1	23.2	112.9
	Meat	Meat	0.8	0.0	0.0	0.0	0.0	0.0	0.0	248.7	53.8	2.8
Unavoidable	Unavoidable	Coconut	39.2	9.8	18.1	12.3	0.0	230.5	25.1	658.5	183.5	167.8
		Sugarcane bagasse	24.7	8.8	39.8	46.3	1.7	189.5	33.8	102.1	66.4	127.5
		Corn straw	47.7	3.6	6.8	27.7	0.2	18.2	0.0	0.0	0.0	0.0
		Peels	117.2	12.3	32.3	26.4	1.1	122.5	0.8	105.5	132.8	281.1
External residues	External residues	External residues	43.1	13.8	22.1	20.4	14.1	72.8	6.3	41.8	109.7	136.1

5.2. COMPARATIVE RESULTS – RIBEIRÃO PRETO AND SÃO PAULO

The results from the waste quantification in Ribeirão Preto can be compared with the results from the gravimetric analysis done by Brancoli (2021) since both used the same methodology for the analysis. Table 3 outlines the results for both municipalities.

Ribeirão Preto had a significantly lower waste generation in comparison to São Paulo. São Paulo wasted on average 23.7 kg per stall, while Ribeirão Preto generated on average 7.4 kg of food waste (Figure 12). In relation to the composition of the waste, São Paulo generated proportionally more unavoidable food waste.

This can be explained by cultural differences on the type of food and snacks sold in the cities' street markets. In São Paulo, the sale of coconut water and sugarcane juice is more prevalent than in Ribeirão Preto. On the other hand, greater quantities of corn husks were observed in Ribeirão Preto due to the commercialization of pamonha, a traditional corn-based food.

The results indicated that for both cities, stalls that operated in larger street markets generated more waste than stalls located in smaller street markets. This must be investigated further in order to determine if the difference in sales volume is the only factor or if there are other factors involved.

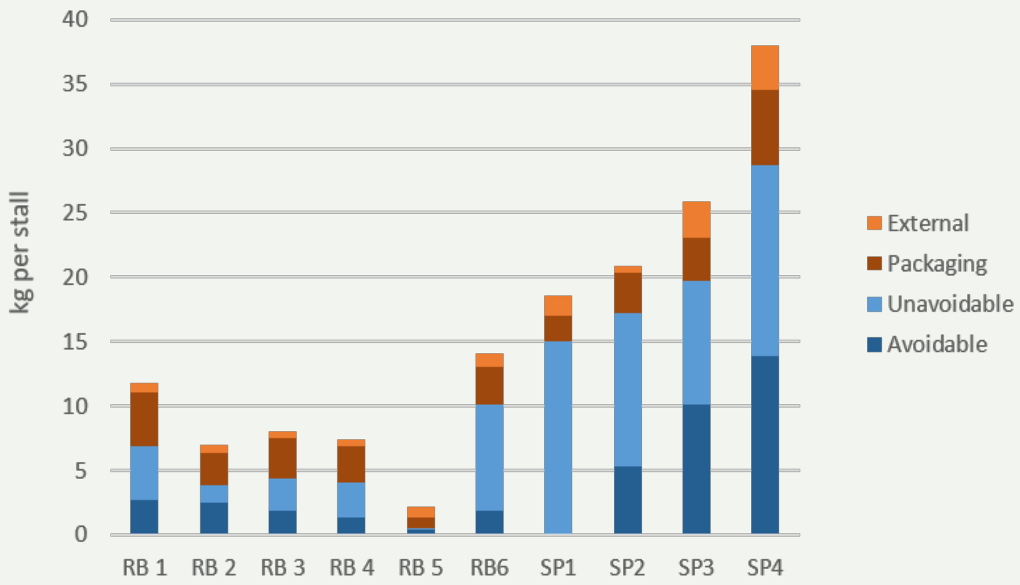


Figure 12. Comparison waste generation per stall Ribeirão Preto and São Paulo (Level 0).

6.

Definition and prioritisation of food products for the risk analysis: environmental impacts

6.1. SÃO PAULO

Figure 13 depicts the total mass and climate change impact of different waste fractions at street markets in São Paulo. The results indicate that the SP4 street market in Belém generated the most food waste per stall, approximately 34 kg. The largest amount of waste was found in the leaves, flowers and stems category, and it is primarily composed of single leaves. SP4 had a climate impact of 26.5 kg CO2 eq. per stall.

SP2 had the greatest environmental impact (58 kg of CO2 eq. per stall), primarily because of the large amounts of meat products wasted. Meat products have the highest impact per unit mass in the climate change impact category. Similarly, SP3 showed the second largest environmental impact, and meat products are responsible for approximately half of it. SP1 had the lowest waste generation and climate change impact, at 17 kg and 11.4 kg CO2 eq. per stall, respectively, and the waste consisted mainly of unavoidable waste.

The results from the waste quantification suggest that the climate impact per stall is directly proportional to the size of the street market. Stalls located at larger street markets tend to waste more and have a higher environmental impact in comparison to stalls operating in smaller street markets. Table 4 shows the results for the climate change impact of the waste fractions generated at street markets in São Paulo.

6.1.1. DATA EXTRAPOLATION FOR SÃO PAULO

The data for waste generation and climate impact were scaled up to the city level based on individual street market waste generation per stall, which was used as the waste factor. The street markets are described in Table 2 and the average waste generation rate was 23.7 kg per stall. There are 871 street markets registered in São Paulo (Prefeitura de São Paulo, 2020). Assuming that all street markets operate during the 52 weeks of the year, there are a total of 45 292 street market occasions per year, amounting to approximately 2.5 million stalls per year. The total yearly food waste generation for street markets in the city of São Paulo was calculated in 50 000 tonnes per year. Avoidable waste was calculated at 18 000 tonnes and

32 000 tonnes of unavoidable food waste were generated (Figure 14). The total annual climate impact caused by the wastage of food was calculated at 87 000 tons of CO2 eq.. The agricultural production of the waste food accounted for just over half of the total impacts, the equivalent of 49 000 tons of CO2 eq. per year. The end of life accounts for the emission of around 38 000 tons of kg CO2 eq. per year (Figure 14).

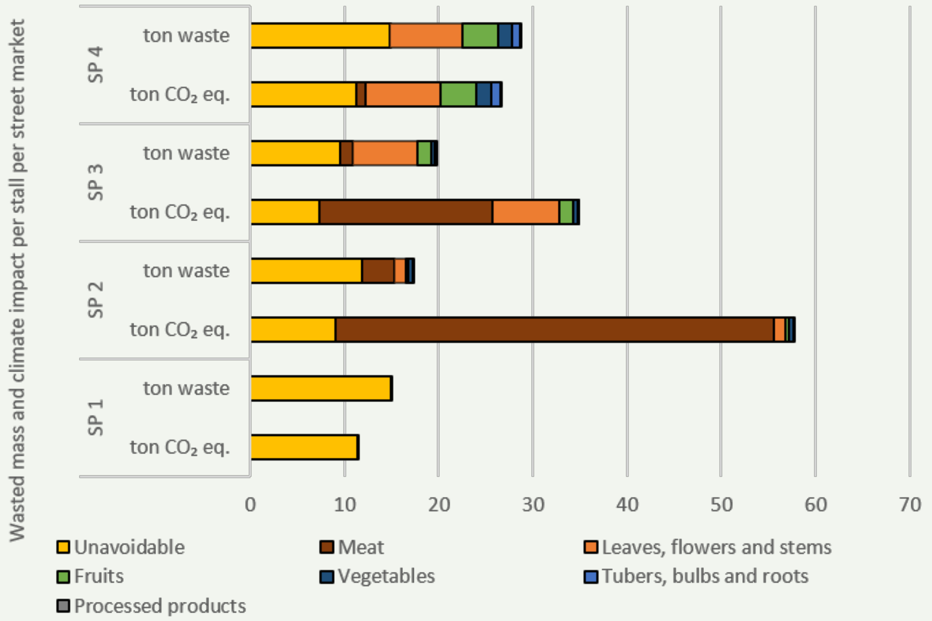


Figure 13. Amount of food waste (kg/stall) and respective climate impact (kg CO2eq) per week in Ribeirão Preto street markets.

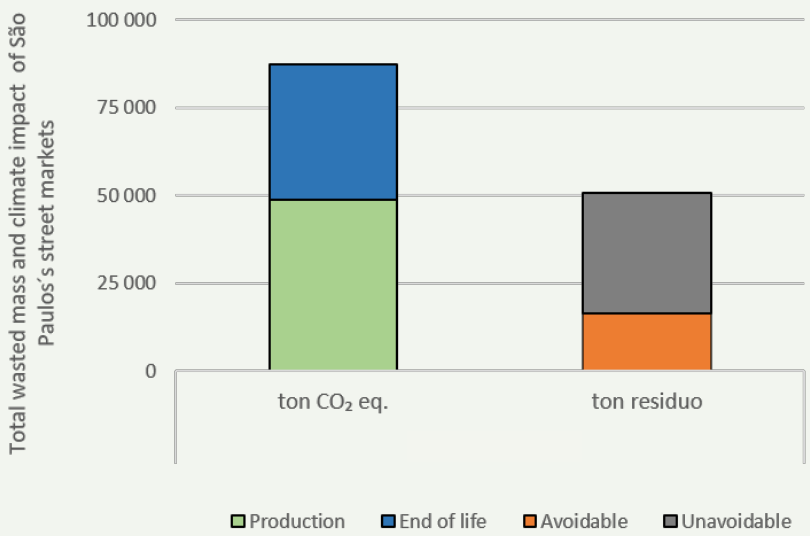


Figure 14. Wasted mass and GWP per year - Total waste generation São Paulo.

Table 4. Climate change impact for food waste in São Paulo (kg CO2 eq. per stall).

Level 0	Level I	Level II	SP 1	SP 2	SP 3	SP 4
Packaging	Packaging	Packaging	0	0	0.04	0.19
Avoidable	Leaves, flowers and stems	Broccoli and Cauliflower	0	0.01	0	0
		Cabbage	0	1.22	7.09	7.86
		Other leaves, flowers and stems	0	0	0.01	0
	Processed products	Processed tubers	0	0	0	0
		Processed fruits and vegetables	0	0	0	0
		Processed leaves, flowers and stems	0	0.02	0.02	0.36
	Tubers, bulbs and roots	Potato	0	0	0.02	0.07
		Carrot	0	0	0.05	0.29
		Onion	0	0	0.01	0.17
		Other tubers, bulbs and roots	0.11	0.05	0.24	1.23
	Vegetables	Tomato	0	0.03	0	0.02
		Pumpkin	0	0	0.01	0
		Bell pepper	0	0	0	0
		Chayote	0	0.47	0.14	0.40
		Other vegetables	0	0.01	0.43	0.24
	Fruits	Banana	0	0.18	0.23	0.51
		Orange	0	0.01	0.22	0
		Watermelon	0	0.03	0.08	0.07
		Papaya	0	0.11	0.58	2.90
		Other fruits	4.76	6.86	3.49	3.27
	Meat	Meat	6.41	1.06	1.26	2.48
Unavoidable	Unavoidable	Coconut	0	0	0	0
		Sugarcane bagasse	0.14	1.10	2.52	5.48
		Corn straw	0	46.53	18.37	0.96
		Peels	0	0	0.04	0.19

6.2. RIBEIRÃO PRETO

The results indicate that on average the street markets in Ribeirão Preto wasted 7.4 kg per stall (Figure 15). The majority of the waste, around 70%, is unavoidable food waste. Leaves, flowers and stems, particularly single leaves, accounted for 14% of the waste. Fruits and vegetables represented 11% and 5% respectively of the total waste generated (Table 5).

Street market RB6, located at Av. Portugal, generated the largest amounts of food waste and carbon dioxide equivalents per stall, 10.13 kg and 8.55 kg CO2 eq. per stall, respectively. Due to the significant amount of unavoidable waste produced, namely coconut, sugarcane bagasse, and peels, the category ranks as the biggest contributor to climate change, accounting for approximately 80% of the total emissions.

Street market RB1 was the second-largest contributor to food waste and climate change, with each stall producing 6.88 kg of food waste and 6.41 kg CO2 eq.. Peels, stems, and corn straw are among the three most significant contributors.

Table 5 reveals that street market RB5 generated the least amount of food waste and kg CO2 eq. per stall, with 0.54 kg and 0.56 kg, respectively. It is worth mentioning that street markets RB6 and RB1 were the biggest and the ones that generated the most food waste and CO2 eq. when the results were normalised per stall. RB5 had the fewest stalls and generated the least waste and kg CO2 eq..

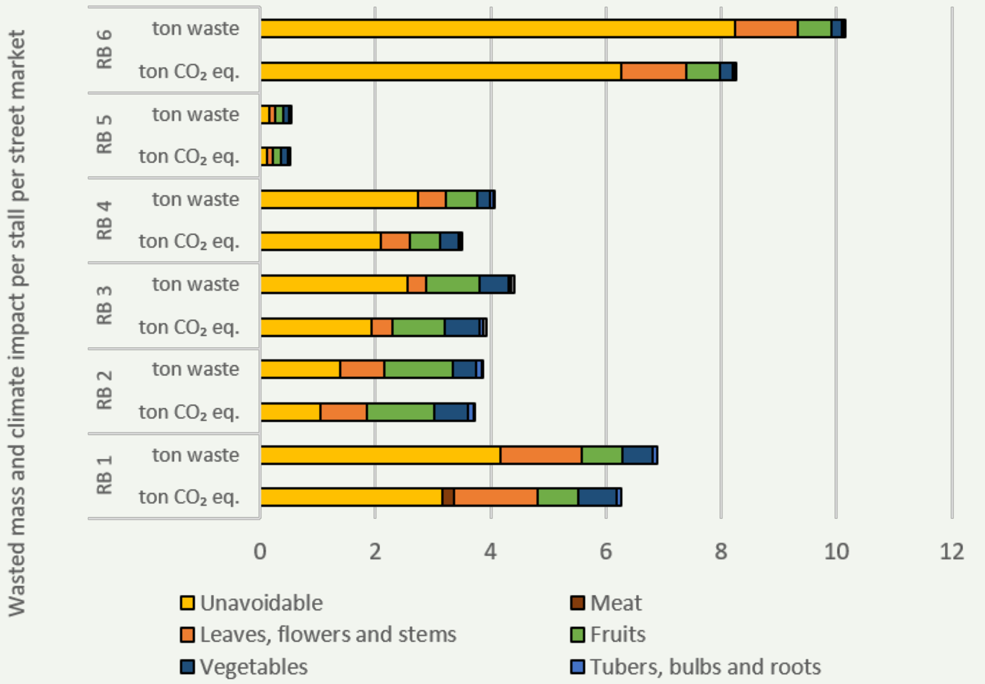


Figure 15. Amount of food waste (kg/stall) and respective climate impact (kg CO2eq) per week in Ribeirão Preto Street markets divided by level I category.

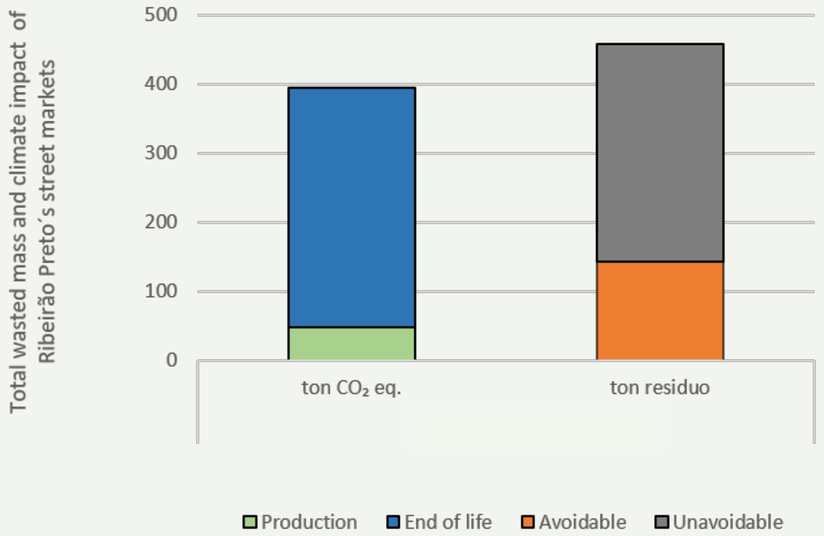


Figure 16. Wasted mass and GWP per year - Total waste generation Ribeirão Preto.

Table 5. Climate change impact for food waste in Ribeirão Preto (kg CO2 eq. per stall).

Level 0	Level I	Level II	RP 1	RP 2	RP 3	RP 4	RP5	RP6
Packaging	Packaging	Packaging	0.02	0.00	0.00	0.01	0.00	0.02
Avoidable	Leaves, flowers and stems	Broccoli and Cauliflower	0.00	0.00	0.00	0.00	0.00	0.00
		Cabbage	1.44	0.81	0.35	0.49	0.10	1.10
		Other leaves, flowers and stems	0.00	0.00	0.00	0.00	0.00	0.00
	Processed products	Processed tubers	0.00	0.00	0.06	0.01	0.00	0.01
		Processed fruits and vegetables	0.00	0.00	0.00	0.00	0.04	0.00
		Processed leaves, flowers and stems	0.03	0.02	0.01	0.01	0.00	0.01
	Tubers, bulbs and roots	Potato	0.00	0.00	0.01	0.00	0.00	0.01
		Carrot	0.02	0.03	0.02	0.01	0.00	0.01
		Onion	0.03	0.05	0.01	0.03	0.00	0.01
		Other tubers, bulbs and roots	0.13	0.05	0.25	0.04	0.05	0.04
	Vegetables	Tomato	0.06	0.01	0.04	0.00	0.00	0.01
		Pumpkin	0.01	0.04	0.04	0.05	0.00	0.01
		Bell pepper	0.03	0.10	0.00	0.02	0.00	0.01
		Chayote	0.43	0.38	0.29	0.21	0.07	0.17
		Other vegetables	0.03	0.10	0.12	0.01	0.00	0.03
	Fruits	Banana	0.39	0.56	0.14	0.18	0.06	0.09
		Orange	0.00	0.00	0.00	0.09	0.00	0.04
		Watermelon	0.06	0.06	0.10	0.06	0.08	0.04
		Papaya	0.22	0.44	0.55	0.18	0.01	0.39
		Other fruits	0.54	0.30	0.36	0.23	0.00	2.58
	Meat	Meat	0.34	0.27	0.80	0.86	0.07	2.12
Unavoidable	Unavoidable	Coconut	0.66	0.11	0.14	0.51	0.01	0.20
		Sugarcane bagasse	1.62	0.37	0.65	0.49	0.04	1.37
		Corn straw	0.20	0.00	0.00	0.00	0.00	0.00
		Peels	0.02	0.00	0.00	0.01	0.00	0.02

6.2.1. DATA EXTRAPOLATION FOR RIBEIRÃO PRETO

The LCA and waste quantification results were extrapolated to the city level using the number of operating street markets as the extrapolation factor. It was estimated that street markets in the city of Ribeirão Preto generate 457 tonnes of waste annually. The annual amount of avoidable food waste was estimated to be 143 tonnes, while the amount of unavoidable food waste was 314 tonnes (Figure 16).

Due to the dominance of unavoidable food waste in the waste composition, the end of life was the phase of the food products' life cycle that contributed the most to the impacts, accounting for approximately 80% of the total emissions. The results indicate that actions that divert organic waste from landfills have the greatest potential to reduce the carbon footprint of food waste generated at street markets in Ribeirão Preto.

6.3. COMPARATIVE RESULTS – RIBEIRÃO PRETO AND SÃO PAULO

The waste quantification and environmental assessment comparison of two cities reveals both similarities and differences. The waste quantities, composition, and climate impacts of the two cities were significantly different. São Paulo generated approximately 23 kg of food waste per stall, with an average carbon footprint of 33 kg CO2 eq. per stall. This is four times and seven times the average food waste per stall and carbon footprint in Ribeirão Preto, respectively (7.4 kg of food waste and 4.6 kg CO2 eq.) (Figure 17).

The composition of food waste in São Paulo street markets was dominated by unavoidable waste, particularly coconut and sugarcane bagasse. However, meat was the product category with the largest contribution to the environmental impacts. Coconut and individual leaves accounted for the second and third largest contributions, respectively. Similar trends were observed in Ribeirão Preto compared to São Paulo, with unavoidable waste being the largest waste category by mass. However, contrary to São Paulo, the category was also the largest contributor to the carbon footprint of the street markets. Figure 17 demonstrates that the primary sources of greenhouse gas emissions in São Paulo are production and end-of-life. The end of life is the sole major source of emissions in Ribeirão Preto.

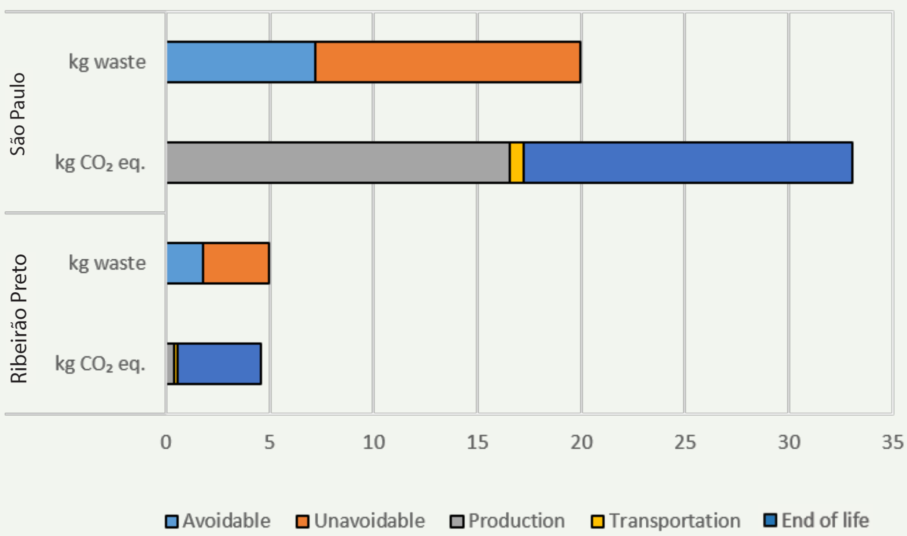


Figure 17. Relative contribution of food waste (kg/stall) and CO2 (kg eq) from São Paulo and Ribeirão Preto of level 0 category.

7.

Definition of food products for the risk analysis

Based on the findings of the environmental assessment, two major product categories were identified as hotspots. The product categories include leaves, flowers, and stems and unavoidable food waste. The latter is composed mostly of sugarcane bagasse and coconut, and its end-of-life environmental implications were significant. Due to resource consumption and emissions at both the agricultural production and end-of-life stages, leaves, flowers, and stems accounted for the greatest amount of avoidable food in relation to environmental impacts and mass.

Future research intends to enhance the hotspot analysis to incorporate other relevant indicators such as economic costs and nutritional value. The economic costs and nutritional loss will be determined based on the features of each specific product. The loss of calories, micronutrients, and macronutrients will be estimated using the comprehensive nutrient profiles of food items.

8.

Risk analysis

The preliminary findings from the interviews with the vendors indicate a number of risk factors and general causes for waste generation. The analysis of particular food fractions will be the focus of future research.

Among the leading causes of food waste cited by vendors are a lack of knowledge of proper storage methods and a lack of access to infrastructure that would permit proper storage and display of products during transportation and sale.

It has been observed improper and excessive handling of products by the vendors and consumers. The results of the interviews revealed inadequate training and a lack of knowledge regarding the handling and stacking of products. In addition, it has been observed a low level of awareness towards food waste among the street market vendors. This lack of information and data on the amount and composition of waste makes it difficult for vendors to determine how much is being lost and what preventative measures are required.

Perishability is a major issue for fruits and vegetables in general. Produce is frequently discarded because it has exceeded its normal shelf life, does not meet aesthetic standards, or for economic reasons. The problem is exacerbated by the length of time between the production and sale of products and, in some cases, by improper packaging, which leads to a decline in product quality (Beretta et al., 2013, Canali et al., 2017, Costa et al., 2022). The varying levels of ripeness of the fruits the vendors received from their suppliers was another cause of food waste, as reported by the vendors.

The literature indicates that transportation and storage prior to the street market vendors purchasing the products can also play a role in waste generation. Transport-related factors such as the type of vehicle and equipment used, as well as a lack of hygiene, can result in product damage and an increase in waste at the point of sale. Therefore, it is necessary to investigate upstream parts of the supply chain (Moraes, 2020).

Many vendors are either unaware of ways to utilize unsold peels, husks, seeds, stalks, fruits, and vegetables, or if they are aware, they choose not to implement these methods. Deficient inventory control also contributes to waste generation due to the lack of control over the amounts purchased and how much is sold and lost. Inadequate forecasting of demand can also be an important risk. Proper knowledge of demand is crucial, particularly for fresh products due to their short shelf life.

The lack of control over the ordering process, e.g., due to minimum possible ordering, also contributes to high levels of waste. This was observed particularly in São Paulo, where the majority of vendors purchase their products from CEAGESP, the biggest wholesaler for fruits and vegetables in Brazil. This may partially explain the disparity in waste levels between São Paulo and Ribeirão Preto.

9.

Conclusions

Street markets are responsible for a relevant share of the food that is commercialised in the retail sector in Brazil (Freitas, 2015). The results of the waste quantification analysis revealed that significant amounts of food are wasted in this part of the supply chain, with significant environmental consequences. This study has investigated the quantities and composition of the food waste generated at six street markets in the city of Ribeirão Preto, in São Paulo state. This study further compared the gravimetric results with the study previously done by Brancoli (2021) for the city of São Paulo.

The environmental consequences of the wasted food, both in relation to the impacts occurring during production and those related to the end of life, were assessed at the product level for São Paulo and Ribeirão Preto. The results indicate that approximately 5 and 23 kg of food per stall were wasted in Ribeirão Preto and São Paulo respectively. The carbon footprint was calculated at 6.7 kg of CO2eq per stall in Ribeirão Preto and 20.2 kg of CO2eq in São Paulo.

The food categories with the highest waste generation were unavoidable food waste and leaves, flowers, and stems. Unavoidable food waste was the major contributor to greenhouse gas emissions in both cities due to the large quantity of waste generated, which accounted for around 65% of the total mass, and the unsustainable waste treatment, which corresponds to between 50-80% of the total climate impact.

This demonstrates the significance of diverting organic waste from landfills, not only to reduce greenhouse gas emissions but also to reduce the loss of nutrients that could be used for soil fertilisation and the contamination of water resources. Meat contributed significantly to the total climate impact in São Paulo. Nevertheless, the quantities in mass are low, probably due to the high economic cost of such products. This suggests that it might be difficult to achieve further reduction.

The combining of the results of the waste quantification with the environmental assessment indicated that priority should be given to preventing food waste from occurring, particularly for leafy products. The results revealed a substantial amount of unavoidable food waste, indicating that diverting these flows from open dumps can reduce greenhouse gas emissions significantly. In order to reduce the amounts and environmental impacts of food waste, it is essential to increase knowledge and infrastructure for the proper handling and storage of products.

10.

References

BERETTA, C., STOESSEL, F., BAIER, U. & HELLWEG, S. 2013. Quantifying food losses and the potential for reduction in Switzerland. Waste Management, 33, 764-773.

BERNSTAD SARAIVA SCHOTT, A. & ANDERSSON, T. 2015. Food waste minimization from a life-cycle perspective. Journal of Environmental Management, 147, 219-226.

BRANCOLI, P. 2021. Guide for waste composition analysis at Brazilian street markets. Borås, Sweden: University of Borås.

BRANCOLI, P., MAKISHI, F., LIMA, P. G. & ROUSTA, K. 2022. Compositional Analysis of Street Market Food Waste in Brazil. Sustainability, 14, 7014.

CANALI, M., AMANI, P., ARAMYAN, L., GHEOLDUS, M., MOATES, G., ÖSTERGREN, K., SILVENNOINEN, K., WALDRON, K. & VITTUARI, M. 2017. Food waste drivers in Europe, from identification to possible interventions. Sustainability (Switzerland), 9.

COSTA, F. H. D. O., DE MORAES, C. C., DA SILVA, A. L., DELAI, I., CHAUDHURI, A. & PEREIRA, C. R. 2022. Does resilience reduce food waste? Analysis of Brazilian supplier-retailer dyad. Journal of Cleaner Production, 338, 130488.

DE BRITO NOGUEIRA, T. B., DA SILVA, T. P. M., DE ARAÚJO LUIZ, D., DE ANDRADE, C. J., DE ANDRADE, L. M., FERREIRA, M. S. L. & FAI, A. E. C. 2020. Fruits and vegetable-processing waste: a case study in two markets at Rio de Janeiro, RJ, Brazil. Environmental Science and Pollution Research, 27, 18530-18540.

ERIKSSON, M. 2015. Supermarket food waste. 2015, Swedish University of Agricultural Sciences

EUROPEAN COMMISSION 2020. Farm to fork strategy: for a fair, healthy and environmentally-friendly food system. DG SANTE/Unit 'Food information and composition, food waste'".

FAO 2017. The future of food and agriculture – Trends and challenges. . Rome

FAO, IFAD & WFP 2015. The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO, 2015. Oxford University Press.

FREITAS, K. A. 2015. Mobilidade urbana e hábitos de compra: efeitos na distribuição e na logística para o varejo. Master, Universidade Federal de Minas Gerais.

IBGE, I. B. D. G. E. E. 2020. Pesquisa de orçamentos familiares 2017-2018: análise do consumo alimentar pessoal no Brasil. Instituto Rio de Janeiro.

ISO 2006a. ISO 14040:2006 Environmental management–life cycle assessment–principles and framework. London: International Standardization Organization.

ISO 2006b. ISO 14044:2006 Environmental Management: Life Cycle Assessments: Requirements and Guidelines. Geneva: International Standardization Organization.

LANA, M. M. & MOITA, A. W. 2020. Qualidade visual e perdas pós-colheita de hortaliças folhosas no varejo: dois estudos de caso no Distrito Federal, Brasil. Embrapa Hortaliças-Documentos (INFOTECA-E).

MBOW, C., ROSENZWEIG, C., BARIONI, L. G., BENTON, T. G., M. HERRERO, KRISHNAPILLAI, M., LIWENGA, E., PRADHAN, P., RIVERA-FERRE, M. G., SAPKOTA, T., TUBIELLO, F. N. & XU, Y. 2019. Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. In: [P.R. SHUKLA, J. S., E. CALVO BUEN-

DIA, V. MASSON-DELMOTTE, H.-O. PÖRTNER, D.C. ROBERTS, P. ZHAI,, R. SLADE, S. C., R. VAN DIEMEN, M. FERRAT, E. HAUGHEY, S. LUZ, S. NEOGI, M. PATHAK, J. PETZOLD, J. PORTUGAL PEREIRA, & P. VYAS, E. H., K. KISSICK, M. BELKACEMI, J. MALLEY (eds.) Food Security.

MORAES, C. C. D. 2020. Mitigação do desperdício de alimentos: práticas e causas na díade fornecedor-supermercado.

ÖSTERGREN, K., BOS-BROUWERS, H. E. J., TIMMERMANS, A. J. M., SOETHOUDT, J. M., GUSTAVSSON, J., HANSEN, O. J., MÖLLER, H., ANDERSON, G., O'CONNOR, C. & QUESTED, T. 2014. FUSIONS Definitional Framework for Food Waste. Gothenburg: FUSIONS N FP7-KBBE-2012-6-311972.

PENNINGTON, J. A. T. & FISHER, R. A. 2009. Classification of fruits and vegetables. Journal of Food Composition and Analysis, 22, S23-S31.

PREFEITURA DE SÃO PAULO. 2020. Lista completa de feiras [Online]. Secretaria de Trabalho e Empreendedorismo. Available: https://www9.prefeitura.sp.gov.br/secretarias/sdte/pesquisa/feiras/lista_completa.htm [Accessed 01-09-2020 2021].

QUESTED, T., INGLE, R. & PARRY, A. 2013. Household food and drink waste in the United Kingdom 2012. Wrap London.

SANTOS, S. F. D., CARDOSO, R. D. C. V., BORGES, Í. M. P., ALMEIDA, A. C. E., ANDRADE, E. S., FERREIRA, I. O. & RAMOS, L. D. C. 2020. Post-harvest losses of fruits and vegetables in supply centers in Salvador, Brazil: Analysis of determinants, volumes and reduction strategies. Waste Management, 101, 161-170.

THOMPSON, F. E., WILLIS, G. B., THOMPSON, O. M. & YAROCH, A. L. 2011. The meaning of 'fruits' and 'vegetables'. Public Health Nutrition, 14, 1222-1228.

UNEP, U. N. E. P. 2021. Food Waste Index - Report 2021. Nairobi.

UNITED NATIONS 2015. Transforming our world: the 2030 agenda for sustainable development, resolution adopted by the general assembly. A/70/L. 1. New York: UN General Assembly.

WERNET, G., BAUER, C., STEUBING, B., REINHARD, J., MORENO-RUIZ, E. & WEIDEMA, B. 2016. The ecoinvent database version 3 (part I): overview and methodology. The International Journal of Life Cycle Assessment, 21, 1218-1230.

WRAP 2009. Household food and drink waste in the UK. Report Prepared by WRAP

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