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QUANTIFYING FOOD WASTE IN RESTAURANTS: A PROPOSAL TO AVOID THE GENERATION OF WASTE

QUANTIFICANDO O DESPERDÍCIO DE ALIMENTOS EM RESTAURANTES: UMA PROPOSTA PARA EVITAR A GERAÇÃO DE RESÍDUOS

CUANTIFICAR EL DESPERDICIO DE ALIMENTOS EN RESTAURANTES: UNA PROPUESTA PARA EVITAR LA GENERACIÓN DE RESÍDUOS

ABSTRACT

Objective: This study aims to quantify food waste in Brazilian restaurants and propose alternatives for its management within the framework of the circular economy.

Methodology: The research was conducted in the city of Chapecó, Brazil, based on the database of companies registered in municipal archives. Researchers visited these establishments to administer a questionnaire, aiming to quantify food waste during preparation, during, and after meals. A total of 177 valid responses were obtained.

Results: The findings reveal that the largest volumes wasted in all three stages of food production consist of vegetables, carbohydrates, meats, and bones. Meat and bones, followed by vegetables and carbohydrates, emerge as the main sources of revenue loss resulting from waste. On average, the analyzed restaurants waste 339 kg of food per month, approximately 13 kg per day, representing an estimated loss of R$ 2,577.85 per month in revenue for each establishment. The results highlight the need for actions aimed at reducing these losses, with circular economy principles proving effective for this purpose.

Practical implications: A set of guidelines is proposed, delineating the key elements necessary for an efficient food waste management system that contributes to the circularity of food in the value chain. Optimisation of menus, adjustable portions, demand forecasting technologies, and designs for reuse through recipes incorporating unused food leftovers, donations, or even reintegration of organic waste through composting are examples of the application of the circular economy in this context.

Originality/value: The study quantifies food waste in the Brazilian context and relates the topic to the circular economy, elucidating circular premises as instruments for waste management.

Keywords: Waste management. Food waste. Food reuse. Circularity in food. Circular economy. Food sector.

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RESUMO

Objetivo: Este estudo tem por objetivo quantificar o desperdício de alimentos em restaurantes brasileiros e propor alternativas para sua gestão no âmbito da economia circular.

Metodologia: A pesquisa foi realizada na cidade de Chapecó, Brasil, e teve como base o banco de dados de empresas registradas nos arquivos municipais. Os pesquisadores visitaram esses estabelecimentos para aplicar um questionário, buscando quantificar o desperdício de alimentos no preparo, durante e após as refeições. Foi obtido um total de 177 respostas válidas.

Resultados: Os resultados revelam que os maiores volumes desperdiçados em todos os três estágios da produção de alimentos consistem em vegetais, carboidratos, carnes e ossos. Carne e ossos, seguidos de vegetais e carboidratos, surgem como as principais fontes de perda de receita resultante do desperdício. Em média, os restaurantes analisados desperdiçam 339 kg de alimentos por mês, aproximadamente 13 kg por dia, representando uma perda estimada de R$ 2.577,85 por mês na receita de cada estabelecimento. Os resultados ressaltam a necessidade de ações que visem à redução dessas perdas, sendo que os princípios da economia circular se mostram eficazes para esse fim.

Implicações práticas: Propõe-se um conjunto de diretrizes, delineando-se os elementos-chave necessários para um sistema eficiente de gerenciamento de resíduos alimentares que contribua para a circularidade dos alimentos na cadeia de valor. Otimização de cardápios, porções ajustáveis, tecnologias para previsão de demanda, design para reutilização através de receitas com as sobras de alimentos não utilizados, doações ou até mesmo a reintegração dos resíduos orgânicos por meio da compostagem são exemplos da utilização da EC nesse contexto.

Originalidade/valor: O estudo quantifica o desperdício alimentar no contexto brasileiro e relaciona a temática com a economia circular, elucidando as premissas circulares como instrumentos para a gestão do desperdício.

Palavras-chave: Gestão de resíduos. Desperdício de alimentos. Reutilização de alimentos. Circularidade na alimentação. Economia circular. Setor de alimentos.

RESUMEN

Objetivo: Este estudio tiene como objetivo cuantificar el desperdicio de alimentos en los restaurantes brasileños y proponer alternativas para su gestión en el marco de la economía circular.

Metodología: La investigación se llevó a cabo en la ciudad de Chapecó, Brasil, y se basó en la base de datos de los negocios registrados en los archivos municipales. Los investigadores visitaron estos establecimientos para administrar un cuestionario, buscando cuantificar el desperdicio de alimentos en la preparación, durante y después de las comidas. Se obtuvo un total de 177 respuestas válidas.

Resultados: Los resultados revelan que los mayores volúmenes desperdiciados en las tres etapas de la producción de alimentos consisten en verduras, hidratos de carbono, carne y huesos. La carne y los huesos, seguidos de las verduras y los hidratos de carbono, aparecen como las principales fuentes de pérdida de ingresos derivadas del desperdicio. De media, los restaurantes analizados desperdician 339 kg de alimentos al mes, aproximadamente 13 kg al día, lo que representa una pérdida estimada de 2.577,85 reales al mes en ingresos para cada establecimiento. Los resultados destacan la necesidad de acciones dirigidas a reducir estas pérdidas, y los principios de la economía circular están demostrando ser eficaces para este fin.

Implicaciones prácticas: Se propone un conjunto de directrices que esbozan los elementos clave necesarios para un sistema eficiente de gestión de residuos alimentarios que contribuya a la circularidad de los alimentos en la cadena de valor. La optimización de los menús, las porciones ajustables, las tecnologías de previsión de la demanda, el diseño para la reutilización mediante recetas con restos de comida sin usar, las donaciones o incluso la reintegración de los residuos orgánicos mediante el compostaje son ejemplos del uso de la EC en este contexto.

Originalidad/valor: El estudio cuantifica el desperdicio alimentario en el contexto brasileño y relaciona la cuestión con la economía circular, dilucidando las premisas circulares como herramientas para la gestión de residuos.

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Palabras clave: Gestión de residuos. Desperdicio de alimentos. Reutilización de alimentos. Circularidad en la alimentación. Economía circular. Sector alimentario.

INTRODUCTION

The handling and preparation of food generate waste at every stage of the food supply chain (Chia et al., 2023), often discarded as refuse (Choi, 2019). Domestic food waste is recognized as a major contributor to the overall food disposal scenario (Chia et al., 2023). However, restaurants also rank among the primary generators of food waste (Principato et al., 2018), significantly contributing to global food wastage (Filimonau et al., 2021).

In restaurants, food waste is linked to leftovers, referring to prepared but unserved food, as well as plate waste, where distributed food remains uneaten (de Oliveira Pontes et al., 2022). These establishments therefore face the challenge of adjusting the quantities of meals to be served daily in order to minimise food waste and make the best use of the ingredients selected for meal preparation.

It is estimated that cities generate more than 2.8 billion tonnes of organic waste annually, of which only 2% is returned to the system (Ellen MacArthur Foundation), with the majority of wasted food ending up in landfills (Food and Agriculture Organization of the United Nations, 2017). Despite losses occurring during production, storage, and transportation phases (Food and Agriculture Organization of the United Nations, 2017), the largest proportion of food waste takes place at the consumption stage (den Boer et al., 2023). For every dollar spent on food, two are lost in health, environmental, and economic costs, with half of these costs (approximately $5.7 trillion per year) resulting from how food is produced and how food waste and by-products are managed (Ellen MacArthur Foundation, 2024).

These high levels of waste are observed across input, rural production, transportation, industrialization, processing, distribution, and consumption sectors accompany a sobering reality: in 2020 alone, an estimated 720 to 811 million people experienced hunger (Food and Agriculture Organization of the United Nations, 2021). This situation is concerning, as the projected growth of the global population will lead to increased food consumption and, consequently, greater waste generation (Tamagisa et al., 2022). Changes in the profile of Brazilian society, with a rising trend in eating out at restaurants (Azevedo et al., 2020), may exacerbate this scenario. Therefore, food waste is one of the main barriers to achieving sustainable and circular food chains (Oroski & da Silva, 2022), and one of the greatest challenges of the 21st century (Tamagisa et al., 2022).

To overcome this challenge, the circular economy (CE) emerges as an alternative. It aims to contribute to material circularity (Morseletto, 2020) and optimizes food usage (Nardi et al., 2020). A current of research focuses on circular gastronomy (Jurgilevich et al., 2016), recognizing valuable resources among discarded foods (Tamasiga et al., 2022).

To address the concerning indicators of food waste, this study aims to map the quantity of waste generated in restaurants located in the city of Chapecó, in the state of Santa Catarina, Brazil, proposing alternatives for its management from a circular economy perspective. Chapecó, situated in western Santa Catarina, is a medium-sized city and a significant agro-industrial hub in Brazil, with a variety of restaurants catering to different clientele, including popular eateries and industrial canteens, providing a comprehensive view of the issue. The city has adhered to the Zero Waste Programme and is committed to generating solutions for underprivileged communities across all production sectors, which justifies its selection for this study.

A review of databases such as Scopus, WoS, and Science Direct revealed no studies measuring food waste in medium-sized cities within Latin America. The inclusion of smaller, non-metropolitan, or non-capital cities is crucial, given the complexity and global nature of the problem. Urban waste management has become one of the greatest challenges for municipalities (Azevedo et al., 2021), and studies indicate that maximising the use of food and waste could yield up to $2.7 trillion annually by 2050 (Ellen MacArthur Foundation, 2024). Additionally, the study of

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the Brazilian context is important, as the country, despite being one of the largest food producers globally, has historically struggled with food insecurity, reappearing on the hunger map after the Covid-19 pandemic as one of the nations facing the most significant challenges (Guarnieri et al., 2023).

Although several studies on the circular economy have been published, the transition in Brazil remains in its early stages, with gaps such as research on the involvement of developing countries to better understand regional differences and strategies to promote the circular economy (Guarnieri et al., 2023). Similarly, despite the growing number of studies on the circular economy in the food sector, there is still a gap regarding food establishments (de Resende Alvares et al., 2022). The approach to food waste in this sector has been understudied (Filimonau et al., 2021; Pontes et al., 2022), and the measures applied in this area have shown limited effectiveness (Filimonau et al., 2021). Furthermore, there is a need to quantify food waste across the supply chain (Tamagisa et al., 2022), and this study aims to fill these gaps by quantifying restaurant waste and generating insights to promote reflection and progress in reducing food waste through the lens of the circular economy in the Brazilian context.

Food waste management is an urgent issue discussed globally and directly relates to the call from the Food and Agriculture Organization of the United Nations (2021) for bold measures to combat food insecurity, malnutrition, and inequality in food access. Moreover, the discussion proposed by this study has the potential to contribute to the advancement of the Sustainable Development Goals (SDGs), particularly SDGs 2, 3, 12, and 16, which focus on eradicating hunger, ensuring healthy lives, promoting responsible consumption and production, and combating climate change, respectively.

The results revealed significant waste volumes at all stages of production and consumption, representing economic losses for the establishments. Furthermore, the predominant practice in the restaurants analysed was the disposal of leftovers in landfills. The quantification of waste and its destination highlights the need for increased environmental awareness among all stakeholders in the supply chain, including owners, employees, and customers of the establishments. In this regard, pathways are suggested for progress towards efficient food waste management through the circular economy. Waste must be avoided at various stages within food establishments, both in production and post-consumption. The circular economy can help address this issue by emphasising the importance of waste prevention through menu optimisation, demand forecasting technologies, and design for reuse through recipes utilising unused food. Donations and composting also emerge as secondary alternatives.

In addition to this introduction, the study is organized as follows: the second section presents the theoretical framework supporting the discussion, bringing relevant aspects of the relationships between food waste and the circular economy. The third section addresses the methodological procedures followed for the research. A fourth section compiles the results of the investigation, the table of relevant evidence, and guidelines for food waste management supported by the circular economy. The article concludes with a final section presenting practical implications for stakeholders and suggestions for future studies.

Food Waste and Circular Economy

Although the current food system has sustained the global population and driven economic development, it remains largely linear, extractive, wasteful, and polluting (Ellen MacArthur Foundation, 2021). Food waste stands out as one of the key economic and environmental challenges of the 21st century (Tamagisa et al., 2022), leading to considerable resource losses throughout the supply chain (Loke et al., 2015). According to data from the Food and Agriculture Organization of the United Nations (FAO), approximately 14% of globally produced food is lost between harvest and retail, while an additional 17% is wasted during retail and consumption activities (United Nations, 2022). These figures are alarming, raising environmental, social, and economic concerns (Kumar et al., 2023).

Food that is produced but not consumed leads to environmental waste, including the loss of resources such as water, energy, and land,

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and is linked to greenhouse gas emissions, which contribute to climate change (Viscardi et al., 2022). Approximately 10% of global greenhouse gas emissions are derived from the food supply chain (United Nations, 2022). Food waste contributes to environmental degradation, represents economic losses, and is linked to increased hunger (Kumar et al., 2023), increasing food insecurity, and negatively impacting the quality of life of populations (United Nations, 2022; FAO, 2021).

Although consumer behaviour has a significant impact on food waste, fiscal incentives and public policies can facilitate the adoption of sustainable practices (Sakaguchi et al., 2018). The food service sector has been a focal point of public policies against food waste due to its significance in waste indices (Pancino et al., 2021).

Particularly in restaurants, despite efforts to mitigate waste, factors such as delivery systems, quality standards, and menu strategies influence food waste generation (McAdams et al., 2019). A study conducted with Canadian restaurants reveals that many establishments measure the amount of food waste and employ strategies such as composting non-edible residues and redistributing food in good condition to staff; however, some restaurants lack such practices and dispose of wasted food in landfills (Sakaguchi et al., 2018).

The issue of food waste has also been addressed in several studies within the Brazilian context. Ng and Sia (2023) examined both external and internal institutional pressures (such as CSR and restaurant size) to explain behaviours related to food waste. De Oliveira Pontes et al. (2022) focused on quantifying waste in industrial restaurant chains, while Ouro-Salim et al. (2023) investigated initiatives to reduce food waste volumes in NGOs in Brazil and Togo. De Resende Alvares, Guarnieri, and Ouro-Salim (2022) explored food waste in sustainable restaurants in the federal capital, and Azevedo et al. (2020) assessed the potential for reusing non-recyclable organic waste to generate energy through biogas. Viscardi et al. (2022) and da Silva Duarte et al. (2021) conducted literature reviews connecting the circular economy with the food supply chain and food waste, respectively.

In this context, the concept of the circular economy emerges as a strategy to address food waste and promote sustainability (Kumar et al., 2023). It has the potential to establish more resilient, equitable, and effective food systems based on collaboration, reducing waste and reshaping the relationship with natural resources (Ouro-Salim et al., 2023). Transitioning to a food system that builds natural capital and is pro-nature is a crucial step in the circular economy (Ellen MacArthur Foundation, 2021).

Ciccullo et al. (2021) highlight that circular economy proposals encompass actions aligned with addressing food waste, focusing on practices aimed at preventing the generation of surplus food. In a circular production system, the aim is to reduce, reuse, recycle, and recover materials at every stage of the supply chain, requiring technological capabilities and engagement from various stakeholders seeking to replace the concept of end-of-life (Kirchherr et al., 2023).

Among the key bottom-up strategies to facilitate the transition to a circular economy is the reduction of food waste. This approach encompasses all stages of the food system, from those who produce and process food, to those who distribute it for consumption, and ultimately, the consumers themselves (Guaresi et al., 2023). In the circular production system, the aim is to close material and energy cycles, aiming to minimize waste generation and the emission of polluting gases (Geissdoerfer et al., 2017). By offering closed-loop circuit designs for food waste recycling, the principles of the circular economy can contribute to mitigating climate change resulting from the emission of gases from food waste, also progressing towards zero waste (Tamagisa et al., 2022). Circular design, for instance, integrates principles of the circular economy, such as the elimination of waste and pollution, the circulation of products and materials, the regeneration of nature, and systemic thinking in the creation of products and services (Ellen MacArthur Foundation, 2021). When applied to the food sector, this approach provides social and economic benefits and supports the long-term resilience of food supply (Ellen MacArthur Foundation, 2021).

According to the principles of the circular economy, food waste should ideally be avoided. If avoidance is not possible, the recovery of the-

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se resources is paramount (Slorach et al., 2019). The optimisation of food waste flow, minimising economic and environmental losses, is exemplified by the Moerman Ladder, which includes the following steps (Rood et al., 2017) :

a) Prevention (preventing food losses);

b) Human food;

c) Conversion to human food (food processing);

d) Use in animal feed;

e) Raw material for industry (bio-based economy);

f) Transformation into fertilizer through composting;

g) Application for sustainable energy;

h) Incineration as waste.

In general, food waste classifications prioritise prevention, which involves avoiding the generation of food waste (Rood et al., 2017). Food valorisation options, depending on the waste situation, start with directing food that is still fit for consumption to human consumption through donation, or alternatively, to animal feed. In the absence of opportunities for human or animal consumption, it is recommended to consider industrial use of waste, composting, energy generation, and, as a last resort, incineration or disposal in landfills (United States Environmental Protection Agency, 2023).

Among the suggested measures to manage food waste in restaurants are: revising purchasing and meal preparation plans, training staff in food preparation and preservation techniques, redesigning process flows, investing in technologies and equipment to optimise production, and establishing supply contracts that penalise food waste (De Oliveira Pontes et al., 2022). Adjusting portion sizes and volumes to meet consumer needs, conducting satisfaction surveys to identify the most accepted menus, and implementing awareness campaigns about the impacts of food waste are additional actions that could mitigate the problem (De Oliveira Pontes et al., 2022).

Governments can also contribute by developing public policies that encourage businesses, such as restaurants, to manage food waste, for example, through tax exemptions for companies engaged in corporate social responsibility activities (Ng and Sia, 2023). A supportive political environment can accelerate the adoption of circular design for food; greater use of upcycled ingredients can help reduce food waste, while regenerative production and the use of diverse and low-impact ingredients can enhance local climate resilience (Ellen MacArthur Foundation, 2021). The issue of food waste may be influenced by geographic, economic, and cultural characteristics, varying from one country to another (Chia et al., 2023). Thus, recognizing the reality of a sector, locality, region, or country is important for delineating effective circular practices that contribute to the prevention of food waste.

According to the Ellen MacArthur Foundation (2024), redesigning the food system can yield five benefits: (i) regenerating natural systems, (ii) combating climate change, (iii) improving access to nutritious food, (iv) supporting local communities, and (v) saving money and creating value.

METHODOLOGICAL PROCEDURES

The research approach is predominantly quantitative with the application of a survey. Consultation was carried out in the database of the City Hall in the city of Chapecó. The database consisted of 729 establishments in the food sector, which includes bars and warehouses, snack bars, other establishments specializing in serving drinks, snacks, tea shops, juices and the like; pizzerias, restaurants, and the like and wiskeria. The intention is to research all the developments. However, there was a lot of resistance on the part of the establishments to answer the survey, and it was possible to obtain data from only 177 establishments, mainly located in the city center. Thus, the sample has a 95% confidence level, with a margin of error of 6% (p = q = 50). The establishments are mainly located in the city center, and the application of the questionnaires sought to approximate the number of establishments by neighborhood, as shown in Table 1.

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Table 1

Distribution of the sample by neighborhood

Neighborhood	Freq.	%	Neighborhood	Freq.	%	Neighborhood	Freq.	%
Centro	92	52.0%	Universitário	7	4.0%	Passo dos fortes	2	1.1%
Santa Maria	16	9.0%	Presidente Médice	6	3.4%	Saic	1	0.6%
Efapi	15	8.5%	São Cristóvão	6	3.4%	Bela Vista	1	0.6%
Maria Goretti	13	7.3%	Engenho Braun	4	2.3%	Cristo Rei	1	0.6%
Seminário	9	5.1%	Alvorada	3	1.7%	Líder	1	0.6%

In order to carry out invitations to participate in the research, priority was given to the 156 establishments registered in the category of restaurants on the list received from the City Hall. Subsequently, the other categories were invited to participate in the research. In total, 6 students, 2 at undergraduate level and 4 at master's level, received training to conduct face-to-face data collection with those surveyed.

The applied questionnaire was adapted from the Food Waste UK and Food Waste Brazil studies, conducted by Embrapa and FGV. It also follows the guidelines of the Pan-European survey for quantification of food waste in the consumer sector (Refresh, 2017). The justification for choosing this questionnaire is especially associated with its validation in an academic and empirical context and with the purpose of generating indicators capable of measuring food waste. Finally, by taking into account indicators similar to those that our study proposes to evaluate in an emerging country.

The data collection, or in other words, the research phases involved the following steps:

a) Previous telephone contact to schedule the date and time of the visit.

b) Previous explanation of the research purposes and the anonymity of the respondent establishment surveyed.

c) Oral application of questions to the respondent.

d) Clarification of doubts, replication of inquiries when necessary, and notes of responses in a physical questionnaire.

e) General guidelines for taking pictures for three consecutive days of waste. Most establishments did not accept our taking photographs, likely out of fear or insecurity, although it was explained that the results would be used only for academic purposes.

f) Acknowledgments for the collaboration and annotation of the respondent's data to forward the collected data, duly analyzed, to the knowledge of the managers, entrepreneurs, and owners of the surveyed establishments.

The choice of the researched subject was made by the restaurant. The initial question addressed to those involved was to identify who had more information about preparing food at the restaurant and managing leftovers. Once identified, a time for the oral application of the questionnaire to the respondent was scheduled.

Once the data were collected, the results were tabulated in cross tables, and the meanings were derived from the mapped evidence. Additionally, the economic losses and the volumes of wasted food were estimated. The waste was quantified in kilograms and grams, in accordance with the responses obtained from the questionnaire (see Appendix).

DATA PRESENTATION AND ANALYSIS

Table 2 presents a brief characterization of the profile of the 177 restaurants surveyed.

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Table 2

Profile of the surveyed restaurants

Types of services offered by restaurants	Absolute Frequency*	Relative Frequency (%)
Snacks	98	55.4
Free buffet	83	46.9
Servings	72	40.7
Buffet kilo	53	29.9
A la carte	37	9.2
A la minuta	22	12.4
Rotation	22	12.4
Other	16	9.0
Subtotal	**177**	---
Shifts in which the restaurant is open		
Midday	139	78.5
Night	130	73.4
Morning	14	7.9
Afternoon	9	5.0
Subtotal	**177**	---
Total meals served per day		
Up to 50 meals	59	33.3
From 51 to 100 meals	54	30.5
From 101 to 150 meals	17	9.6
From 151 to 200 meals	16	9.0
From 201 to 250 meals	3	1.7
From 251 to 300 meals	8	4.5
From 301 to 350 meals	3	1.7
From 351 to 400 meals	4	2.3
From 401 to 450 meals	-	0.0
From 451 to 500 meals	2	1.1
More than 500 meals	5	2.8
Did not inform	6	3.4
Subtotal	**177**	---
Days of the week when the restaurant serves meals		
5 days	19	10.7
6 days	105	59.3
7 days	53	29.9
Other frequency	0	0.00
Subtotal	**177**	100.0
Existence of separation of leftover meals from other materials that can be reused from your restaurant		
Yes	91	51.4
No	58	32.8
Partially	28	15.8
Subtotal	**177**	100.0
Destination of leftover meals		
Destination for landfill	116	65.5
Animal feed destination of rural producers	67	37.9
Donation to employees and others	49	27.2
Reusable material for recycling	27	15.3
Reuse next day	22	12.4
Another option	8	4.5
Destined for the Mesa Brasil Program	2	1.1
Subtotal	**177**	---

Note: *the number of citations is greater than the number of observations due to multiple responses.

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It can be seen in Table 1 that most of the researched enterprises offer buffets and snacks. The predominant office hours are noon and night. Establishments that offer up to 100 meals a day for 6 days a week predominate. There is a predominance of concerns about separating leftovers from other materials that can be reused in restaurants. A variety of different destinations for leftovers were reported, with a significant percentage of 65.5% of establishments allocating part of their leftovers to landfills.

Table 3 shows the attributes pursued by the restaurants. The scale measures the importance perceived by the respondents, where 1 is less important, and 4 is very important.

Table 3

Attributes of prepared food

Attributes	**1**	**2**	**3**	**4**	**Total**
Healthy	25	58	34	60	177
Tasty	6	53	43	75	177
Cockroach	141[a]	20	11	6	177
Fresh	6	46	89[a]	36	177
Total	**177**	**177**	**177**	**177**	---
Concerns	**1**	**2**	**3**	**4**	**Total***
I have enough food in the restaurant to prepare	38	14	8	117[b]	177
I don't have a lot of food in the restaurant to prepare	113[b]	5	11	48	177
Food is easy to prepare	36	62[b]	46	32	176
Meet customer preferences	4	10	35	128 [b]	177
Meet regional customs	19	59 [b]	31	68	177
Total	**102**	**142**	**160**	**357**	**761**

Grades:

a Actual frequency significantly higher than the theoretical frequency Chi2 = 442.99, gl = 12, 1-p => 99.99%.
b Actual frequency significantly higher than the theoretical frequency. Chi2 = 455.83, gl = 20, 1-p => 99.99%

It is worth highlighting the concern of the interviewees with the quality of the prepared food. The cost is considered to be very unimportant (1 on the scale), by 141 (79.7%) of the respondents, while 60 respondents consider a healthy food to be very important (they assigned 4 on the scale to this item), and 75 rated it as high. food taste (4 on the scale). It is noteworthy that the major concerns of the interviewees corroborate with meeting customer preferences and having enough food in the restaurant to prepare it properly.

To determine the amount of food waste generated by restaurants, three stages of the food process were investigated: a) waste during food preparation; b) waste due to consumption during the meal; and c) waste post preparation. Food preparation is understood as the stage of washing, separating, cutting, preparing, and cooking food (the steps that happen in the kitchen before taking the food to the customer's table). Food waste during meals is defined as that which occurs when the customer serves the food and its leftovers on the plate when the meal is finished. Post-preparation food waste is understood as the excess of prepared food, that is, the leftovers of meals after all customers have served themselves.

Table 4 shows the reported responses, as well as the total wasted, by type of food and at each stage of the process.

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Table 4

Daily food waste in restaurants - Observed frequency and quantity calculated, by type of food, per stage

	Vegetable		Greenery		Fruit		Meat		Carbohydrates		Bones		Shells		Seeds		Dessert		Drinks	
	Freq.	kg	Freq.	kg	Freq.	kg	Freq.	kg	Freq.	kg	Freq	kg	Freq.	kg	Freq.	kg	Freq.	kg	Freq.	Litres
Waste during preparation																				
No answer	21	0	3	0	30	0	26	0	22	0	29	0	35	0	35	0	---	---	---	---
I have no waste	65	0	55	0	122	0	117	0	104	0	126	0	107	0	131	0	---	---	---	---
Less than 1 dish per day	51	51	72	72	17	17	18	18	29	29	14	14	17	17	7	7	---	---	---	---
From 1 to 5 dishes per day	30	75	27	67.5	6	15	7	17.5	9	22.5	2	5	6	15	0	0	---	---	---	---
From 6 to 10 dishes per day	7	56	9	72	2	16	7	56	9	72	2	16	4	32	0	0	---	---	---	---
From 11 to 15 dishes per day	2	26	7	91	0	0	2	26	2	26	0	0	0	0	0	0	---	---	---	---
From 16 to 20 dishes per day	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	---	---	---	---
Above 21 dishes per day	1	21	4	84	0	0	0	0	2	42	4	84	8	168	4	84	---	---	---	---
Totals (Kg)		229		386.5		48		117.5		191.5		119		232		91	---	---	---	---
Waste during the meal																				
No answer	38	0	17	0	30	0	22	0	2	0	25	0	34	0	35	0	31	0	28	0
Up to 50 grams	96	4.8	79	3.95	133	6.65	95	4.75	81	4.05	119	5.95	130	6.5	139	6.95	133	6.65	124	6.2
From 51 to 100 grams	37	2.78	57	4.28	9	0.68	32	2.4	56	4.2	26	1.95	9	0.675	2	0.15	10	0.75	14	1.05
From 101 to 150 grams	4	0.5	13	1.62	3	0.38	22	2.75	26	3.25	7	0.88	3	0.375	0	0	0	0	5	0.62
From 151 to 200 grams	1	0.18	5	0.88	2	0.35	5	0.88	9	1.57	0	0	1	0.175	1	0.18	1	0.175	3	0.52
From 201 to 250 grams	1	0.22	4	0.90	0	0	1	0.22	0	0	0	0	0	0	0	0	2	0.45	1	0.22
From 251 to 300 grams	0	0	2	0.55	0	0	0	0	3	0.82	0	0	0	0	0	0	0	0	0	0
Above 301 grams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.6
Totals (Kg)		8.48		12.18		8.05		11		13.9		8.77		7.72		7.28		8.02		9.22
Post-meal waste																				
No answer	35	0	11	0	31	0	26	0	4	0	34	0	35	0	35	0	31	0	28	0
I have no waste	88	0	73	0	128	0	103	0	79	0	132	0	129	0	139	0	131	0	130	0
Less than 1 dish per day	31	31	44	44	13	13	25	25	34	34	7	7	9	9	0	0	12	12	9	9
From 1 to 5 dishes per day	20	50	41	102.5	4	10	19	47.5	45	112.5	3	7.5	3	7.5	3	7.5	3	7.5	7	17.5
From 6 to 10 dishes per day	3	24	3	24	1	8	4	32	11	88	1	8	1	8	0	0	0	0	1	8
From 11 to 15 dishes per day	0	0	4	52	0	0	0	0	2	26	0	0	0	0	0	0	0	0	2	26
From 16 to 20 dishes per day	0	0	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0	0	0
Above 21 dishes per day	0	0	1	21	0	0	0	0	1	21	0	0	0	0	0	0	0	0	0	0
Totals (Kg)		105		243.5		31		104.5		299.5		22.5		24.5		7.5		19.5	177	60.5

Note1: For the purpose of calculating the quantity in Kg., The scalar average of the interval was considered. Thus, for example, for the interval with the option of "from 1 to 5 courses", 3 courses ((5 + 1) / 2) were considered. For the first and last categories of the scale, the measurable limits were considered. Example: for the interval with the option of "Less than 1 dish per day" 1 dish was considered. And, for the option "Above 21 dishes per day", 21 dishes were considered

With the average prices by food category, Table 5 shows the total wasted, the different stages of the process, as well as the amount in Reais, taken in October 2019.

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Table 5

Daily and monthly amount wasted by type of food and estimated cost

Food	Waste			Daily Total (Kg)	Food value [1] (R$/Kg)	Total daily loss (R$)	Total monthly loss[2] (KG)	Total monthly loss (R$)
	Preparation	During	After					
Vegetables	229	8.475	105	342.475	4.19	1,434.97	8,467.07	35,477.00
Greenstuff	386.5	12.175	243.5	642.175	4.19	2,690.71	15,876.60	66,522.94
Fruits	48	8.050	31	87.05	6.01	523.17	2,152.15	12,934.43
Meat	117.5	11.000	104.5	233	18.50	4,310.50	5,760.50	106,569.20
Carbohydra-tes	191.5	13.900	299.5	504.9	7.80	3.938.22	12.482.73	97,365.26
Bone	119	8.775	22.5	150.275	18.50	2,780.09	3,715.27	68,732.56
Shells	232	7.725	24.5	264.225	6.01	1,587.99	6,532.48	39,260.19
Seeds	91	7.275	7.5	105.775	6.01	635.71	2,615.09	15,716.71
Desserts		8.025	19.5	27.525	10.00	275.25	680.51	6,805.05
Drinks (lt)		9.225	60.5	69.725	4.00	278.90	1,723.82	6,895.29
Totals				**2.427.13**	**Kg**	**R$ 18,455.51**	**60,006.21**	**R$ 456,278.63**

Note 1: Average price of fruits and seeds = R $ 6.01; Average price of vegetables and greenstuff = R $ 4.19; Average meat price = R $ 18.5; Average price of carbohydrates = R $ 7.80.
Note 2: Month with 24.72 days of activity, calculated from survey data

The analysis of Table 5 indicates that the largest volume of waste is associated with vegetables, accounting for 59% of the total monthly waste (35 tonnes per month). The second largest volume is from carbohydrates, representing 21% (12 tonnes per month), followed by meats and bones, with 16% (9.5 tonnes per month). These three categories constitute the largest volumes of waste, with vegetables standing out as the leading group both in terms of quantity wasted and economic impact.

Financially, the waste of meats and bones has the most significant impact, representing a loss of R$ 175,000 (38% of the total value wasted). Vegetables follow with losses of R$ 169,000 (37%), and carbohydrates with R$ 97,000 (21%). These figures demonstrate that, although vegetables represent the highest physical volume of waste, the economic impact of waste from meats and bones is more substantial.

The largest physical volumes wasted are vegetables (35 tonnes / month - 59%), followed by carbohydrates (12 tonnes / month - 21%) and meat and bones (9.5 tonnes / month - 16%). Another 2.4 tonnes (4%) come from desserts and drinks. The revenue losses caused by the waste generated in the three stages of food analysed in this research are R $ 175 thousand in meat and bones (38%), followed by vegetables (R $ 169 thousand - 37%) and carbohydrates (R $ 97 thousand - 21 %). Another R $ 13 thousand (3%) are for drinks and desserts. Considering a total of 177 establishments surveyed, there is an average waste of 339 kg / month (or 13k / day) per restaurant, with loss of revenue of R $ 2,577.85 / month / establishment. It is interesting to note that the average volumes of leftovers found in our study are close to those found by Busato et al. (2012) in a study carried out in the same city in a community restaurant, subsidized by the City Hall

DISCUSSION OF RESULTS

Food losses generated in the surveyed restaurants represent potential sources of economic losses, the volume of which indicates that, indeed, these establishments contribute to the global food waste (Filimonau et al., 2021) and require attention regarding the development of public policies. The food waste observed among the 177 participating restaurants in the research alone could alleviate the hunger of over 3,000 people per month.

We observed concerns about reuse among the restaurants, but the predominant practice is still to send leftovers to landfills. Brazil is a developing country in which the circular economy still faces sustainability paradoxes (Jabbour et al., 2020). Even in countries more advanced in terms of the circular economy, such as Belgium, about 61% of restaurants do not separate organic waste

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for specific disposal (Vink et al., 2019). However, among Canadian restaurants surveyed by Sakaguchi et al. (2018), only 14% of establishments directed their waste to landfills.

This observed difference between countries reinforces the point made by Chia et al. (2023) that food waste is influenced by different factors and may differ among countries. Moreover, each establishment has varied operational procedures in terms of days and operating hours, for example, which also influence the generation of leftovers, as pointed out by McAdams et al. (2019).

To address the observed waste, it is necessary to invest in refining the competencies, practices, and worldviews of all actors working along the supply chain (Shove, 2014). When applying the circular economy to food systems, there is an interest in reducing the amount of waste generated in the food system (Jurgilevich et al., 2016). This can occur through the reuse of food, the utilization of by-products and food waste, and nutrient recycling. Measures should be implemented at both the producer and consumer levels, i.e., the chef and the customer who serves or receives meals in the restaurant. Finally, it is necessary to implement efficient alternatives in waste and surplus food management. The management of waste and surplus food refers to the use of by-products and food waste in the production phase and the reuse of food to avoid excess in the consumption phase, primarily based on the competence and capacity of the consumer.

The specific factors of each country must be taken into account in formulating actions aimed at sustainable waste management (Chia et al., 2023). Therefore, mapping waste indicators in a pilot project is an important advancement. Based on the mapped percentages, it is possible to design new alternatives, tailored to reality, to contribute to the reduction of food losses. Based on the presented indicators, some ways in which the circular economy can contribute to reducing food waste in the restaurant sector are proposed and presented in Table 6.

Table 6

Daily and monthly amount wasted by type of food and estimated cost

Key Elements	Descriptive	Actors
Awareness of the change towards circularity of materials	Changing requires creating a new organizational culture. This requires specific training and qualifications. Universities, Sebrae, Ministry of Education and restaurant owners can engage in this path.	– Teachers – Governors – Managers – Restaurant owners
Communication of circular economy practices	It demands the creation of educational campaigns, booklets, flyers, radio ads, advertisements on television to show and disseminate good practices in circular economy.	– Nucleus of Circular Economy, – Federal government – Universities – Schools – Sebrae – WWW-F Brasil – Embrapa
Sharing Platforms	Disseminate the good examples of food sharing in force in Brazil. Get inspired by the platforms used by other countries, such as Too Good to Go (London), Foodsharing (Germany), Sainsbury's (United Kingdom), Fopo Food Poder (Sweden). Connecting Food (Brazil), Fruta Imperfeita (Brazil).	– Nucleus of Circular Economy, – Federal government – Universities – Schools – Sebrae – WWW-F Brasil – Embrapa
Action Plan for the Circular Economy in Brazil	That consolidates a set of goals, deadlines, and responsible persons that are based on the prevention, reduction, reuse, recovery, and recycling of materials and energy. Replacing the "end-of-life" concept of the linear economy with new circular flows of reuse, restoration, and renovation.	– Governors – Multinationals – Small and medium-sized enterprises
Online database of enterprises that adopt the circular economy in Brazil	Create a platform to share best practices in circular economy between different sectors.	– Universities – Government
Instituting the circular economy as a new production model in the food sector	Create an environmental and social pre-qualification system for suppliers that provides for selection (supplier sustainable classification). This selection of local suppliers will sell mainly to local markets (insertion in product distribution networks at km 0, direct sales, agreements with the network of facilities dealers). Support through industry symbiosis mechanisms, through the activation of partnerships and agreements for the building partnership between the parties destined to the exchange of resources, such as materials, products, waste, energy, services, knowledge, etc.	– Restaurant owners – Government – Multinationals – Small and medium-sized enterprises
Emphasis on circular product and zero waste	Create goals and indicators that contribute to offering meals that adopt the perspective of a circular product, that is, made with clean energy, healthy food, of local origin, whose leftovers are destined for a second use, allowing to characterize the chain as being of zero waste.	– Restaurant owners – Restaurant employees – Customers

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The specific factors of each country must be taken into account in formulating actions aimed at sustainable waste management (Chia et al., 2023). Therefore, the mapping of waste indicators in a pilot project is a significant advancement.

FINAL REMARKS

This study aimed to map the amount of waste generated in restaurants located in the city of Chapecó, Brazil. Research evidence indicates that this waste is significant in meals and after preparation, and the main disposal method for the waste remains landfill.

This article underscores the necessity of greater integration of circular economy principles within food establishments, particularly in light of changes in Brazilian society, such as the increased frequency of dining out (Azevedo et al., 2020). Quantifying food waste raises awareness of the economic and environmental losses associated with it, providing an empirical foundation for the efficient management of such waste, which could help reduce the volume of food discarded in landfills.

To achieve this, the involvement of various stakeholders, including suppliers, staff, and customers, is essential. Circular economy principles should be incorporated from the preparation stages, in line with the Moerman Ladder (Rood et al., 2017). Waste should be prevented through menu optimisation, adjustable portions, demand forecasting technologies, and design for reuse through recipes using leftover food. Subsequent alternatives include by-products, donations, or even reintegration of organic waste through composting.

This article offers valuable insights into advancing the circular economy and reducing food waste by addressing significant gaps, particularly in the Brazilian context and medium-sized cities such as Chapecó. By providing data on waste in rural areas and the restaurant sector, the article may inspire new public policies and local initiatives focused on waste reduction and circularity. The connection with Sustainable Development Goals (SDGs), such as hunger eradication and responsible consumption, enhances the study's global relevance.

The mapped results are useful for multiple actors:

a) For food establishment owners: to raise awareness of the financial losses due to food waste and to develop strategic actions through menu planning and demand forecasting. Additionally, investment in staff training is recommended, as significant waste was noted during food preparation.

b) For public managers: to create awareness campaigns on the importance of reducing food waste, and to provide incentives for sustainable restaurants.

c) For the restaurant union: to set specific goals for the sector to reduce food waste.

d) For social assistance entities: so that they can legally contribute by offering alternatives for the enterprises; they can donate the surplus to entities that shelter people in a state of social vulnerability.

e) For customers: to make them aware of the damage they cause to society by "throwing away food".

f) For universities: to articulate new research to minimize food waste and try to circumvent it.

The theoretical contribution of the study is associated with an unprecedented mapping, through the realization of a pilot project in an average city, of approximately 210 thousand inhabitants, which recently joined the Zero Waste Program. New research initiatives in the sector are necessary to create ways of progress in reducing losses and waste and in generating healthy habits for the entire population. Whether in the consumption of healthy foods or in the reduction of waste.

As a limitation of the research, one can observe the resistance of the owners and managers of the restaurants to adhere to the research. There was an insecurity in the environment, making them feel uncomfortable about contributing to the research. This resistance also makes it more difficult to map food waste indicators more precisely. All data generated in terms of measuring waste were estimated based on the perception

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of respondents surveyed. Therefore, they carry a bias.

For future studies, it is proposed to proceed with research based on available innovations that can be useful to combat food waste. Research should explore in more depth the circular business models and their contribution to the success of combating food waste.

The authors report there are no competing interests to declare

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-APPENDIX

Questionnaire Number_____

Questionnaire on Food Waste in Restaurants in Chapecó (SC)

Thank you for participating in this survey.
This questionnaire is part of the inquiry to restaurant managers in the city of Chapecó to assess food waste. In this survey, we would like to ask you some questions about how food is handled in your restaurant. There are no right or wrong answers; it is about understanding your situation. This questionnaire will take approximately 10 minutes.

1) How many years has the restaurant been in operation? _____ Years

2) What does your establishment serve?
( ) Portions
( ) Snacks
( ) Buffet
( ) Food by weight
( ) Buffet
( ) À la carte
( ) À la carte
( ) Other _____

3) During which shift(s) is the restaurant open to the public:
( ) Lunchtime
( ) Evening
( ) Others _____

4) On average, how many meals are served in your restaurant/establishment per day? _____ meals.

5) How many days a week are meals served at your establishment?
( ) Up to 5 days - Monday to Friday
( ) 6 days - Monday to Saturday
( ) 7 days - Monday to Sunday
( ) Other frequency _____

We would like to know what is most important to you regarding the attributes of the food you prepare. Rank the following attributes in order (from most to least important): Healthy. Tasty. Cheap. Fresh.

1 (least important) Food is_____
2 Food is_____
3 Food is_____
4 (most important) Food is _____

7) We would also like to know your concern when planning the quantity. Rank your most frequent daily concern in ascending order (number 4 for the most important and 1 for the least important):
( ) I have enough food in the restaurant to prepare
( ) I DO NOT have much food in the restaurant to prepare
( ) The food is easy to prepare
( ) Meeting customer preferences
( ) Meeting regional customs

8) Is there separation of leftovers from meals from other materials that can be reused in your restaurant?
( ) Yes
( ) No
( ) Partially

9) What do you usually do with the leftovers from meals at your restaurant?
( ) Allocate to the Mesa Brasil Program
( ) Reuse the next day
( ) Feed rural animals
( ) Donation to employees and others
( ) Sent to the landfill
( ) Reusable material sent for recycling
( ) Other option _____

BLOCK A - Waste in Food Preparation: Food preparation refers to the stage that involves washing, separating, cutting, preparing, and cooking food (everything that happens in the kitchen before taking the food to the customer's table)

10) Indicate which types of food generate the most waste during food preparation for meals (select the 2 items that are most wasted)
( ) Vegetables
( ) Greens
( ) Fruits
( ) Meats

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( ) Carbohydrates (rice, potatoes, cassava, etc)
( ) I don't have waste
( ) Others. Please specify: _____

11) On a 7-point scale, indicate the average level of waste for the following foods during preparation (on average per day - reference one plate of food normally used in a meal):

Items	No wastage (1)	Less than one plate per day (2)	1 to 5 medium plates per day (3)	6 to 10 medium plates per day (4)	11 to 15 medium plates per day (5)	16 to 20 medium plates per day (6)	Above 21 medium plates per day (7)
Vegetables							
Greens							
Fruits							
Meats							
Carbohydrates							
Bones							
Peels							
Seeds							
Others							

Others. Please highlight which ones _____

BLOCK B - Food Waste During Meals: Food waste during meals is understood as that which occurs from the moment the customer serves the food and its leftovers on the plate when they have finished the meal.

12) Indicate the average level of food waste during the meal (on average per person who dines in your restaurant per day)
( ) Up to 50 grams (One serving spoon equals 50 grams)
( ) From 51 to 100 grams
( ) From 101 to 150 grams
( ) From 151 to 200 grams
( ) From 201 to 250 grams
( ) From 251 to 300 grams
( ) Above 301 grams

13) On a 7-point scale, indicate the average level of food waste for the following items during the meal (on average per person who dines in your restaurant per day - reference: one serving spoon equals 50 grams)

Itens	No wastage (1)	Up to 50 grams (2)	From 51 to 100 grams (3)	From 101 to 150 grams (4)	From 151 to 200 grams (5)	From 201 to 250 grams (6)	Above 251 grams (7)
Vegetables							
Greens							
Fruits							
Meat							
Carbohydrates							
Bones							
Peels							
Seeds							
Desserts							
Beverages							
Others							

Others. Please highlight which ones _____

BLOCK C - Post-Food Preparation Waste: Post-food preparation waste is understood as the excess food prepared, that is, the leftovers from meals after all customers have served themselves.

14) Please select one option for each question. Indicate the type of food with the highest level of waste after preparation (on average per day)
( ) Vegetables
( ) Greens
( ) Fruits
( ) Meat
( ) Carbohydrates (rice, potatoes, yams, etc.)
( ) Desserts
( ) Juices
( ) I have no waste
( ) Others. Please specify: _____
_____

15) On a 7-point scale, indicate the type of food with the highest level of waste after preparation (on average per day) of:

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Items	No waste (1)	Less than one plate per day (2)	1 to 5 medium plates per day (3)	6 to 10 medium plates per day (4)	11 to 15 medium plates per day (5)	16 to 20 medium plates per day (6)	Above 21 medium plates per day (7)
Vegetables							
Greens							
Fruits							
Meat							
Carbohydrates							
Bones							
Peels							
Seeds							
Desserts							
Beverages (juice, soda, beer)							
Outhers							

Others. Please highlight which ones _____

QUESTIONNAIRE - PART 2

Please take photos of your discarded food throughout the day (preferably lunch, snack, and dinner). You can take photos of the plate and/or the pan. Therefore, do not throw away the food to be discarded in the pan and on the plate before taking the photos! Take at least 3 photos per day for 3 days! Send the photos to (49) _____ (Each questionnaire applicator provides their phone number in this item).

Thank you very much for your participation. With the information collected, we can help in the proper handling and disposal of food in Brazil, and improve retail practices.

RECENTER SEND THIS MESSAGE TO THE RESTAURANT FOR 3 CONSECUTIVE DAYS AFTER THE QUESTIONNAIRE APPLICATION - We appreciate your valuable collaboration in sending us the photos. We would like to remind you to take at least 3 photos during the day showing the food waste in your restaurant.