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Food losses and wastes in Brazil: a systematic review

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ABSTRACT
Globally, it is estimated that approximately a third of the food produced is lost or wasted. Reducing half of these losses would make it possible to increase the availability of food for another 1 billion people. Specifically, in Brazil, the amount of lost and wasted food, if used, would be enough to achieve food security, considering as a restriction for this security, the availability of food for purchase. In this context, the objective is to identify methodologies that measure losses and food waste in Brazil. For this, a systematic review of the subject was made. It can be observed that there are a few studies that quantify food losses and wastage in the country. The largest concentration of these studies is in the distribution and consumption stages of the food supply chain. Information is available from food lost and waste, mainly in the consumption and distribution phases. Otherwise, in the other phases of the supply chain, food loss and waste values in Brazil are still incipient or non-existent. Studies that identify these values can contribute to the generation of more accurate information on the subject, being able to raise the values referring to food loss and waste of the country.
Keywords: supply chain; food secutity; sustainability; hungry.

Perdas e desperdícios alimentares no Brasil: uma revisão sistemática

RESUMO
Estima-se que, globalmente, aproximadamente um terço dos alimentos produzidos sejam perdidos ou desperdiçados. No entanto, a redução de metade dessas perdas tornaria possível aumentar a disponibilidade de alimentos para mais 1 bilhão de pessoas. Especificamente, no Brasil, a quantidade de alimentos perdidos e desperdiçados, se utilizados, seria suficiente para alcançar a segurança alimentar, considerando como uma restrição para essa segurança, a disponibilidade de alimentos para compra. Nesse contexto, o objetivo é identificar metodologias que mensurem perdas e desperdício de alimentos no Brasil. Para isso, foi realizada uma revisão sistemática do assunto. Pode-se observar que existem poucos estudos que quantificam perdas e desperdícios de alimentos no país. A maior concentração desses estudos está nos estágios de distribuição e consumo da cadeia de suprimento de alimentos. As informações estão disponíveis a partir de alimentos perdidos e desperdiçados, principalmente nas fases de consumo e distribuição. Nas demais fases da cadeia de suprimentos, os valores de perda e desperdício de alimentos no Brasil ainda são incipientes ou inexistentes. Estudos que identifiquem esses valores podem contribuir para a geração de informações mais precisas sobre o assunto, podendo elevar os valores referentes à perda e desperdício de alimentos no país.
Palavras-chave: cadeia de suprimentos; segurança alimentar; sustentabilidade; fome.

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1. INTRODUCTION

The quest for ensuring food and nutrition security is related to the challenge of having a world free of hunger and malnutrition through a food production that attends the needs of the world's population. This product requires an economically, socially and environmentally sustainable system to prevent the creation of problems related to food production, such as the depletion of natural resources (FAO, 2017a). Although over the years there has been a progressive reduction of hunger, it still affects around 800 million people worldwide (FAO et al., 2015). Also, the global population increase is a trend. It is estimated that by the middle of this century it excesses 9 billion people, surpassing 11 billion by the end of the period. This projection, combined with excessive consumption, population aging, climate change, accelerated urbanization, natural disasters, and economic and financial crises, results in a panorama of uncertainties about food availability that serves the entire population. (FAO, 2009, 2017a).

It is observed that the increase in food consumption is not only connected to the increase in production, other factors, such as the reduction of losses and wastes, can be considered alternatives to the solution of the problem. Approximately 1.3 billion tons of food is wasted annually on our planet (FAO, 2013). The area used to produce what is being wasted amounts to the territories of Canada and India, this waste transforms the labor and natural resources used in this production into wastes that do not serve the productive purpose, feed and nourish people (FAO, 2013). Thinking about ensuring future food safety, reducing losses and waste is considered one of the most promising measures (Foley et al., 2011; Gustavsson et al., 2011; Mechanical Engineers, 2013; Parfitt et al., 2010). Among the aim of Agenda 2030, Goal 12, mark 3, considers reducing half of the world's food waste in consumption, retail sales and reducing losses in the production chain, to achieve sustainable development (ONU, 2015).

In this meaning, the reduction of losses and waste can contribute incisively on the amount of food offered (Priefer et al., 2016). However, along the supply chain, the causes for the occurrence of losses and waste vary according to the specific conditions and the local situation in each country (Gustavsson et al., 2011). In developing countries, losses are mainly associated with inefficient harvesting and poor processing quality. Moreover, in the case of developed countries more often occurs the waste, substantial of food wastage or are simply discarded (Gustavsson et al., 2011; Krishna Bahadur et al., 2016). Generally, both facts represent an important aspect of the inefficiency of food systems (Kummu et al., 2012). There

is a necessity to evaluate the effects that reducing food losses and waste can cause financially, socially and environmentally, so it demonstrates values to society so that this characteristic can be reversed (Williams et al., 2015). In this way, the objective is to identify methodologies that measure food losses and waste in Brazil, considering that the country stands out globally for its agricultural production. For this, a systematic review was carried out on the subject.

2. FOOD LOSSES AND WASTE IN LATIN AMERICA AND THE CARIBBEAN

Food Loss and Waste (FLW) refers to the edible parts of plants and animals harvested or produced but which are not even consumed. The loss of food is related to an agricultural process or technical limitation in storage, infrastructure, packaging, which food is lost before reaching the consumer. The waste results from the negligence or conscious decision to discard the food before or after spoiling (Lipinski et al., 2013).

There are several aspects to be considered concerning food losses and wastage. There are studies that consider the loss in the production process due to the action of pests or natural phenomena (example: hail, drought, excessive rainfall), but most works define and/or account for losses starting from the harvest (Gustavsson et al., 2014; Parfitt et al., 2010). It also occurs that consumer behavior, losses, and inefficiencies in agricultural production, play a substantial role in the amount of food waste generated (Alexander et al., 2017). The definitions of losses/wastage starting from harvesting can be seen in Table 1.

Table 1. Definitions for food losses/wastage in the supply chain stages.

Food loss			Waste of food	
Production	**Postharvest and storage**	**Processing**	**Distribution, Retail**	**Consumption**
Loss occurs during and shortly after harvest	Loss occurs during handling, drying, local/regional transport, and storage	The loss occurs during processing and local or industrial treatment and packaging	The loss occurs during processing and local or industrial treatment and packaging	The waste occurs at household and consumption level

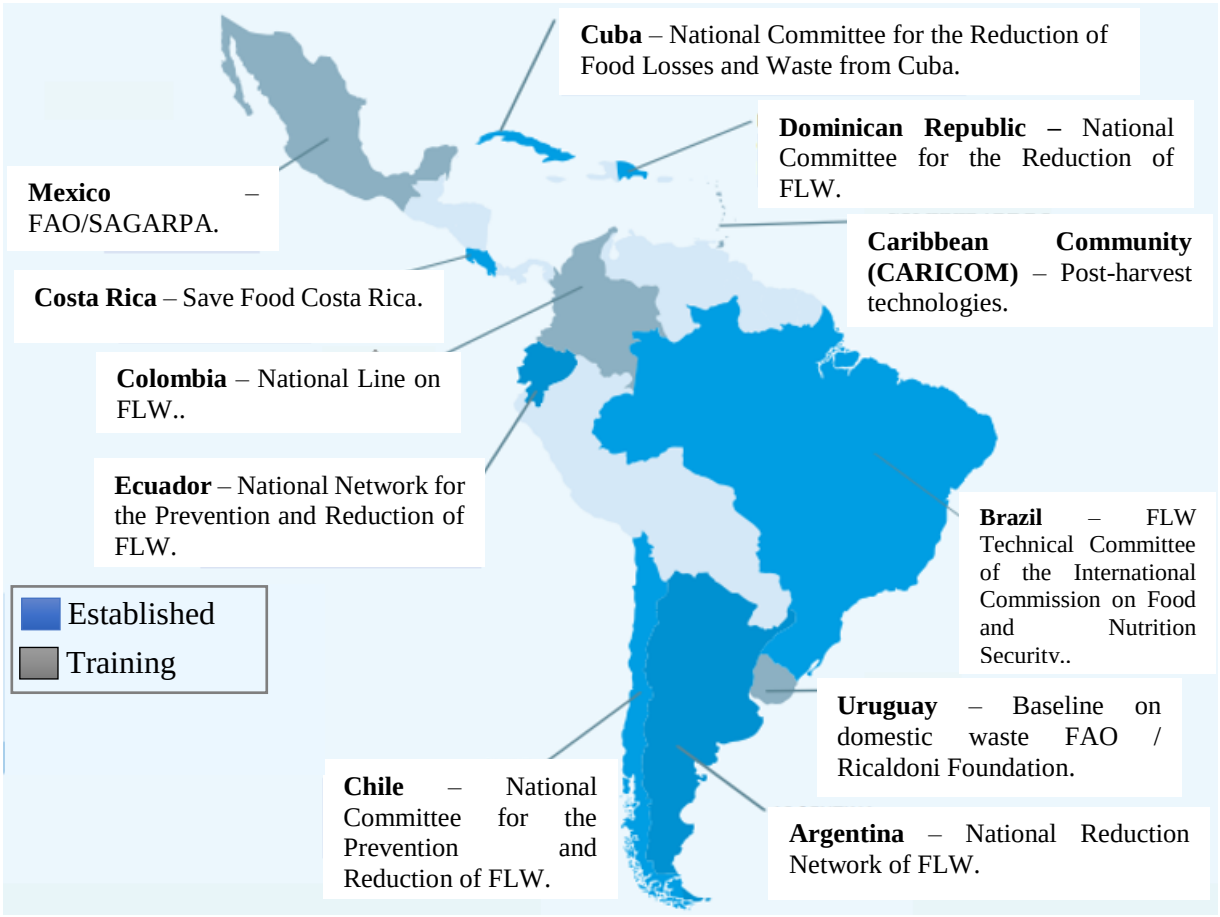
Source: Adapted from Gustavsson et al. (2014) and Parfitt et al., (2010).

Regarding the worldwide distribution of losses and waste (residue), developing and developed countries generate most of their waste at different stages. The underdeveloped countries generate the largest amount of unused food with the losses, which are mainly associated with inefficient harvesting, inadequate storage facilities, and poor processing quality.

Already developed countries, the most frequently generated losses are concentrated on waste, given the low cost of food and large amounts of food that spoil without being consumed or are just rejected, even though they may be fit for consumption (Krishna Bahadur et al., 2016).

Concerning to Latin America, the fight against FLW is carried out in different ways, according to the country (Figure 1), from its committees and working groups. It is noted that they are in distinct stages about their constitution, being classified (i) information and (ii) established. However, it is observed that many countries in Latin America have no committees. This feature is worrying if it is considered that hunger is a global problem that needs to be tackled and that government actions are essential to this issue.

Figure 1. Status of national committees and intersectoral working groups in Latin American and Caribbean countries



Source: FAO (2017a).

Latin America causes about 6% of the total wasted and lost food in the world, only with the reversion of FLWs, in this region, it would be possible to feed 300 million people (FAO, 2011). Considering only direct sales to consumers, it would be possible to supply the caloric

requirement of 36 million people, higher than the population registered as food insecure in the region of the continent (FAO, 2016). Brazil maintains similar characteristics in FLW, compared to Latin America. In 2013, 7.2 million people faced starvation in the country. Contrastingly, the amount of food lost and wasted in the same year could be enough to achieve food security in the nation (FAO, 2015).

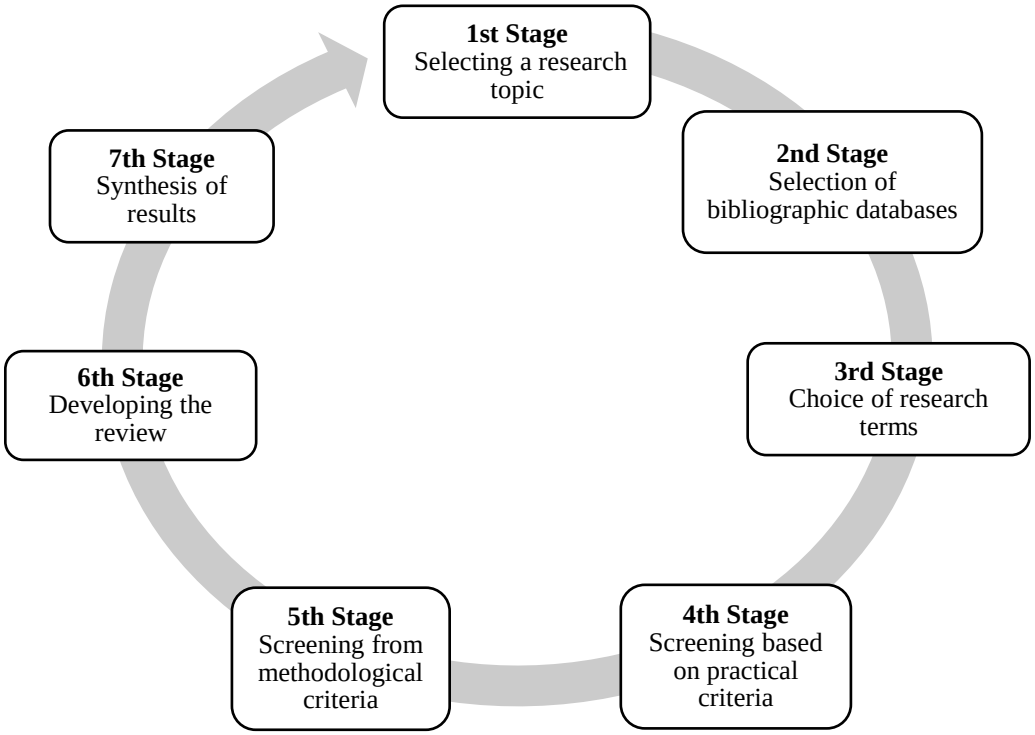
From this context, the Community of Latin American and Caribbean States (CELAC), in partnership with the FAO, approved in 2015 the CELAC Action Plan for Food Security, Nutrition and Eradication of Hunger in 2025, with the purpose of reducing food problems (FAO, 2015). In the same year, the 2030 Agenda for Sustainable Development was launched, in which these countries adhered and committed to halve per capita food losses and wastage by 2025. Thus, there is a relationship between the actions proposed by CELAC and the UN for the countries of Latin America and the Caribbean, in favor of reducing hunger. For this, the strategy includes an articulated regional alliance from national committees (FAO, 2016). There is also the initiative to insert the gender issue into the context, so public actions value women's work to reduce hunger and there is equal access between men and women to land (FAO, 2017b).

In the specific case of Brazil, there is a need to overcome the dilemma of being one of the richest countries in natural resources and having part of its population with problems of food restriction due to lack of access, productive availability, among others. It should be noted that over the last few decades the country has been struggling to reduce this problem through governmental action that has made hunger no longer a structural problem (FAO, 2017c). Also, the country has gained prominence about the agricultural volumes produced, which has been contributing to the reduction of hunger in the world. To make new progress in the country, it is believed that investments in sustainable production programs, technical assistance and knowledge creation that generate good rural management practices will assist the country in its progress against hunger (FAO, 2017c). To consolidate the country's food system, seeking the food security of the population (FAO, 2016).

3. METHODS

The organization of this review follows the guidelines made by Fink (2010) for systematic reviews and applied by Suess-Reyes and Fuetsch (2016), composed of seven stages (Figure 2).

Figure 2: Stages for the development of systematic review



Source: research data

After the selection of the research topic, defined the use of databases (i) Google Scholar, (ii) Scientific Electronic Library Online - SciELO and (iii) Capes Periodic. From the descriptors "Brazil and Food waste", "Brazil and Food losses" and "Brazil and Post-harvest losses", to access the scientific production related to the subject. Regarding the practical criteria, articles were selected in English and Portuguese (Portuguese is the official language of the country, so it was included), without temporal determination. The methodological criteria were selected from peer-reviewed publications and available in academic journals. The selection of articles included in the review referred to quantified food losses and wastes studies produced in Brazil. Several methods can be used to measure the FLW, which are available in Annex 1.

4. RESULTS AND DISCUSSION

Table 2 indicates the number of articles identified in the literature, referring to the subject searched, from the descriptors and other characteristics defined for the elaboration of this research. A total of 431 articles related to the subject were identified, of which 18 articles refer to the quantification of FLW in the country. In common, there is a characteristic related to using information in percentage and data of approximate estimates from international sources

(FAO and USDA). In this case, these sources consider the region of location and the similarity between countries to estimate the value of the quantities of FLW. It happens also that when observed the number of published works, it can be mentioned the necessity to expand academic research on the subject, given the global importance of this theme.

Table 2. Scientific bases, keywords, and number of articles found in the researches

	Scientific Bases		
Used key-words + Brazil	**Google scholar**	**Scielo**	**Capes Periódic**
"Food waste"	26	75	89
"Food losses"	7	3	9
"Post-harvest losses"	33	52	138
Total	66	130	236
Grand Total			432

Source: Made by the authors (2018).

Most of the studies that quantify losses and wastes in Brazil are case studies and were generally carried out at the consumption and distribution stages (Table 3).

It is believed this feature should be related mainly to the ease of data collection, where the weighting methodology can be easily employed.

The FLW values are variable in the different phases of the supply chain because they are influenced by the specificities of each product. As an example, the consumption and distribution phase varies between 10% and 30% of the total of meals produced and not consumed, and are similar to each other (Leinig et al., 2017, Gonzáles et al., 2017, Galian et al., 2016, Pistorello et al., 2015, Parisoto et al., 2013, Pikelaizen e Spinelli, 2013, Fugii et al., 2010, Ricarte et al., 2008). In the post-harvest, processing, and transportation phases, the products still differ according to their food group, chain size, type of processing and logistics (Rocha et al., 2017, Ribeiro et al., 2014, Foscaches et al., 2012, Costa et al., 2011, Costa e Caixeta Filho, 1996)

Another point to be observed is that losses in production were not evaluated, probably because of the difficulty in determining it, because it is an expensive process that requires time and labor for its execution. The most commonly found in the literature are those referring to using new technologies, mainly in pest control. Concerning the Brazilian studies that quantify the FLW, even if these are reduced, there is low international visibility by the fact that the majority is published in the Portuguese language. Studies at global levels did not use data obtained in Portuguese to estimate food losses and waste, as it can be observed in the FAO study (2011).

Table 3. Studies using methodologies that measure the losses and food waste

Authors	Objectives	Supply Chain Phases	Methods	Results
Guerra et al (2018)	To evaluate the main causes of post-harvest losses in bell peppers, potatoes and onions marketed in the fairs and supermarkets of Santarem - Para state	Distribution	Physiological, microbiological and mechanical verification.	The highest percentage identified in the losses is microbiological.
Leinig et al (2017)	To assess food waste in a mid-sized restaurant	Distribution and consumption	Measurement of quantities	10% of the total served is wasted
Gonzáles et al (2017)	To evaluate food waste from a Food and Nutrition Unit	Distribution and consumption	Weighing of quantities and intervention	Total leftovers of 28.4, reducing to 20.2% after intervention
Rocha et al (2017)	To measure the physical and economic losses observed in the supply chain of wheat mills	Processing	Application of questionnaires and estimation of losses	The losses represented 11.41%, which would totalize U$ 29.98 million (1U$ = BR$ 3.98)
Oliveira et al (2016)	To analyze the waste of food served at a hospital lunch	Distribution and consumption	Weighing	30% of waste
Galian et al (2016)	Quantifying food waste in an industrial restaurant	Distribution and consumption	Weighing	The leftovers from the Restaurant totaled 15.92% of the total produced, while the waste of customers on their plates was 4.19%
Nascimento et al (2016)	Measure and quantify losses incurred in the transport of maize between the property and the warehouse	Transportation	Interviews	A 28-ton capacity truck can lose up to 350 kg of maize in a journey of 1,000 km, which represents 1.25% of the cargo being lost
Pistorello et al (2015)	To evaluate the generation of solid residue from the realization of a mass balance of food in a restaurant of a hotel.	Distribuição e consumo	Weighing of residue	About 14 to 20% of food waste is generated by customers in the different services offered in the restaurant. 50% of this untouched.
Ribeiro et al (2014)	To evaluate post-harvest losses in table grapes during operations conducted in packing houses	Processing and distribution	Weighing	3.9% of the grapes were lost in the packing house, whereas in the producer's market it was 1.5%
Parisoto et al (2013)	To analyze and reduce food waste in a Popular Restaurant	Distribution and consumption	Weighing	The leftover of food on plate measured was 4.77% and after the intervention was reduced to 3.39
Pikelaizen e Spinelli (2013)	Assessing Food Waste from a Food Nutrition Unit at a Private School	Consumption	Weighing	The average of leftovers was 28.6% and the average orts were 21.1%
Foscaches et al (2012)	To characterize the logistics and post-harvest handling of fruits and vegetables in eight cities	Transport and storage	Interviews	91% of questioned affirm that packaging is efficient; 20% of respondents said they did not store the products; 52.72% of the transport vehicles used are open trucks.
Costa et al (2011)	To evaluate the origin, quantify and describe post-harvest losses of papaya 'Hawaii'	Distribution	Weighing	When received at the distribution center 11% of the fruits are discarded: 45% for mechanical injury, 41% for damage and 13% for broken fruits
Fugii et al (2010)	To evaluate the generation of food leftover before, during, and after an awareness campaign against food waste in a Food and Nutrition Unit	Distribution and consumption	Weighing	The percentage of losses and wastage reduced after the awareness campaign
Ricarte et al (2008)	Assessing Food Waste in a University Restaurant	Distribution and consumption	Weighing	The total waste by the diners was 8.3%
Nonino-Borges et al (2006)	To verify the occurrence of the waste, in the form of rest of food, in the Unit of Food and Nutrition of the Emergency Unit of a Hospital	Consumption	Weighing of the remains and estimated the cost	The remains totaled 31% and their estimated cost was US$7.580,00
Fehr e Romão (2001)	To verify the waste of vegetables in the distribution and at the consumer level	Distribution and consumption	Data obtained from market management; wholesale/retailer data collected by the authors	Food in deteriorating represents 8.8% of the weight of household waste; The waste of fruits and vegetables was estimated at 16.6% by weight in the commercialization phase and at the consumer level it was 3.4% of all household waste
Costa e Caixeta Filho (1996)	To understand the reasons for the high loss rates for the tomato, giving a greater focus to the post-harvest, and to estimate them for the marketing	Transportation and distribution	Mathematical model	From the tillage to the consumer it is lost 18.57% of the total of tomatoes; The producer is the most impaired by the reduction of post-harvest losses since with it there is a reduction of prices

5. CONCLUSIONS

Brazil does not have many studies to determine food losses and wastes. Still, being aware that the quantity of FLW is high, and thinking about food security and nutrition and a resilient food production system, the search for the reduction of this is essential. Especially if considered that the country has high-income inequality and this feature can compromise people's access to nutritious food. The reduction of FLW can assist in cheapening the cost of food in the country, increasing food supply in the domestic market to facilitate access to food of the population with the lowest income in the country.

Information is available from FLW, mainly in the consumption and distribution phases. Otherwise, in the other phases of the supply chain, FLW values in Brazil are still incipient or non-existent. Studies that identify these values can contribute to the generation of more accurate information on the subject, being able to raise the values referring to FLWs of the country. Thus, there is a need for the development of this research to identify the FLW in the various stages of the supply chain in the country, to contribute to the formation of public policy.

In addition, the methods of collection referring to food losses and wastes are not standardized. Thus in 2017 the World Resources Institute (WRI) has developed the standard for accounting and reporting food loss and waste (FLW Standard), which provides requirements and instructions for quantifying and reporting what is lost and wasted in the supply chain and form a global database (WRI, 2017). This initiative makes it possible to have information that can be compared over time, and between states and counties in a country or even between countries. This possibility enables the monitoring of the performance of FLW from a government initiative to reduce it.

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ANNEX 1. Methodologies for measuring losses and waste of food.

METHODS	DESCRIPTION	ADVANTAGE	DISADVANTAGES
Direct weighing	Use of weighing device to quantify unused food mass	- Accuracy; - Little uncertainty about inventory data	Required effort
Counting (Basic, scans, scales)	Evaluation of the number of elements that compose the FLW and using results to determine the weight	- Low cost - A high degree of precision - FLW causes could be detected	Not very useful when FLWs are in a mix of many elements
Evaluation by volume	Use of devices combined with water displacement or visual assessment	If FLW is in a container, it is easier and cheaper to evaluate the volume to weigh	Requires the density factor application to convert the volume to weight, which can lead to inactivity
Analysis of waste composition	Physical separation, weighing, and categorization of FLW	- Overcomes many problems of other methods; - Used combined with another method	- Costs determine sample size; - Requires a high level of experience; - Not all food flows can be analyzed
Files	Frequent analysis of files, such as waste transfer, to quantify unused foods	- It is often cheaper than new studies - Studies are based on actual measurements, data may be more accurate	The method used to generate data may not be clear
Field journals or operations	Use of weighing device to quantify wasted mass of food	- Information in "real time"; - Qualitative information	By providing a way to record FLW not by using a formal collection system, it is not easily quantified
Researches	Compilation of information on quantities of FLW or other information (attitude, beliefs, et cetera)	- Costs and time; - Participation; - Value-added information	- Difficulty to convey important concepts - Respondent's individual bias - Unreliable answers
Mass balance	Measurement of inputs and outputs at different stages of the food supply chain	- The flexibility of application to products or substances; -Procedures established for its use; - Free software available; - Easy access to information	-The data from a range of sources are required and may requisite conversion; - Some weight reductions are not related as FLW
Modeling	Use of terminology and mathematical approach to estimate FLW, based on the interaction of multiple factors	- Relatively low costs; - Can generate provisional data susceptible to subsequent improvements with measurements or approximations	- Unsubstantiated assumptions can be included in the model; - Mathematical relationships between model elements can be applied inappropriately
Proxy data	They may include older data than the scope of temporary inventory coming from a different geographical area, or that are drawn from another sector than the defined one	Less expensive than methods that measure or estimate the amount of food wasted	Less precise, due to the application of suppositions

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