Gestão & Regionalidade

Received: 05/03/2022
Accepted: 07/11/2022

Food losses and waste in the context of the Circular Economy: main quantification methodologies

Perdas e desperdícios de alimentos no contexto da economia circular: principais metodologias de quantificação

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Resumo
Este trabalho apresenta como tema central a perda e desperdício de alimentos e o reaproveitamento dos resíduos agroalimentares resultantes das perdas. Nesse sentido, teve como objetivo geral entender quais são as principais metodologias de quantificação das perdas e desperdício de alimentos e quais as estratégias têm sido adotadas para redução do desperdício e o reaproveitamento dos resíduos agroalimentares à luz dos preceitos de Economia Circular. Como resultado constatou-se quatro metodologias utilizadas internacionalmente: Padrão para contabilizar e relatar Perdas e Desperdício de Alimentos; Metodologia da Organização das Nações Unidas para Alimentação e Agricultura; Metodologia da União Europeia baseada no Projeto Fusion e Hierarquia de Recuperação de Alimentos. Ambas aderem ao conceito de Economia Circular baseado na redução de insumos e recursos naturais, minimização e recuperação dos resíduos agroalimentar por meio de reutilização, reciclagem e composição de subprodutos que são reinseridos na cadeia de suprimentos alimentar.
Palavras-chave: perdas e desperdício de alimentos, resíduo agroalimentar, economia circular.

Abstract
This paper presents as a central theme the loss and waste of food and the reuse of agri-food residues resulting from losses. In this sense, the general objective was to understand what the main methodologies for quantifying food losses and waste and what strategies have been adopted to reduce waste and reuse agri-food waste in the light of Circular Economy precepts. As a result, four methodologies used internationally were found: Standard for accounting and reporting Food Loss and Waste; United Nations Food and Agriculture Organization Methodology; European Union methodology based on the Fusion Project and Food Recovery Hierarchy. Both adhere to the Circular Economy concept based on the reduction of inputs and natural resources, minimization and recovery of agri-food waste through reuse, recycling and composition of by-products that are reinserted into the food supply chain.
Keywords: food losses and waste, agrifood waste, circular economy

Citation: Carvalho, D. S. M., Alves, A. F., Silva, C. L. (2024). Food losses and waste in the context of the Circular Economy: main quantification methodologies. *Gestão & Regionalidade*, v. 40, e20248437. https//doi.org/10.13037/gr.vol40.e20248437

1 Introduction

The expansion of the population brings an important dilemma. On the one hand, the food production is sufficient to meet world demand, given that the total grain production is more than necessary to meet the global demand (FAO, 2019). On the other hand, more than 24% of the world's population is in a state of food insecurity, that is, 1.9 billion people do not have access to safe and nutritious food that meets their dietary needs for an active and healthy life (FAO, 2020). This paradox is due to some factors, like the waste of about a third of all food produced in the world, which is the equivalent of 1.3 billion tons of food, approximately (FAO, 2018).

Moreover, the disposal of organic waste directly impacts the environment through the waste of natural resources and carbon dioxide emissions equivalent to uneaten food, in addition to the socioeconomic damage (ABRELPE, 2020). The reuse of food waste helps to avoid rubbish and can help fight hunger through donations to a food bank, for instance. The recovery of inedible parts of waste can be used to compose by-products for other purposes (Fassio & Tecco, 2019).

An alternative approach to reducing the generation and reuse of waste is the Circular Economy (CE). This is an economic system model that aims to eliminate waste and continuous use of natural resources, by means of employing reuse, recycling, sharing, repair, renovation and remanufacturing, in order to create a closed loop system, which minimizes waste generation, in addition to contribute to reduce the environmental pollution (Ellen MacArthur Foundation, 2017).

The interest of researchers in managing food loss and waste (FLW) and the management of such waste from a CE perspective is increasing. The evolution of scientific production, of an interdisciplinary nature, on the subject became significant between 2014 and 2019. This is in agreement with discussions on food security in the European Union, during this period (Salim et al., 2022)

Therefore, through the problem presented and the possible solutions arising from CE, the purpose of this research is to survey the main methodologies of analysis of FLW, with adherence to CE precepts, to find alternatives to the problem of waste, through the reuse of agro-food rubbish.

2 Brazilian Context

Brazil is one of the main food producers in the world and is among the ten countries that waste the most in the world. According to calculations by the Food and Agriculture Organization of the United Nations (FAO), 26.3 million tons of food are lost or wasted in Brazil. Waste occurs at all stages of the production process, from the beginning at the plantation, until its transport, processing, distribution and consumption. Approximately 35% of all Brazilian agricultural production is lost or wasted (FAO, 2019).

Regarding the retail distribution of food, the Brazilian Association of Supermarkets (ABRAS) reported that the sector recorded 1.79% losses on gross sales in 2020. This index represented an estimated total of R$ 7.6 billion. The items that suffered the biggest losses were fruits and vegetables (FV), frozen meals, bakery, soft drinks, beers and meat. According to the association, the main factors that drove losses are expired validity, corresponding to 37.4%, and product unfit for sale (damaged), 29.1% (ABRAS, 2021).

In wholesale distribution, the causes of FLW may be related to improper packaging, requirements for aesthetic and quality standards, improper handling (excessive "hand touching"), inadequate facilities or storage, and logistical issues (EMBRAPA, 2017).

Waste in food consumption by the Brazilian consumer is discussed by Araujo (2018), who emphasizes the importance of culture for a comprehension of FLW. The concern about food safety was the most common reason, according to the author, for food disposal. However, the preference for freshness and excessive quantities during food preparation are factors that contribute to the waste of suitable food for consumption.

A direct consequence of FLW is the generation of agro-food waste. Brazil occupies the fourth place in the world ranking in waste generation, with about 79 million tons per year, behind only China, United States and India. The propensity for the coming years is for growth, reaching an annual generation of 100 million tons in 2030 (ABRELPE, 2020).

In view of this, one of the biggest problems faced in the country is the inadequate disposal of waste, in addition to the difficulty of many municipalities in implementing management plans effectively. The National Solid Waste Policy (PNRS) instituted by Law No. 12,305, of August 2, 2010, was a regulatory framework for the problem of solid waste in Brazil, however, after 10 years of implementation of the law, many planned actions have not yet been adopted in most Brazilian municipalities (ABRELPE, 2020).

The same association informed that of the total number of Brazilian municipalities, 46.12%, carried out the disposal of solid urban waste in sanitary landfills, which was considered as adequate. The rest (53.88%), which corresponds to 3,001 municipalities distributed in all regions of the country, disposed their waste in inappropriate places, such as open air discharges (dumps) or controlled landfills (26.8% and 27.08%, respectively), which do not have a system or necessary measures to protect people's health and the environment against damage and degradation.

Despite the landfill being considered by the Ministry of the Environment as an adequate final disposal of waste, there are environmental, social and economic alternatives for the treatment of organic waste. Thus, it is necessary to adopt strategies to combat waste, and measures for processing, recovering and reusing solid waste.

3 Circular Economy

Since the second half of the 20th century, studies have been carried out with the aim of finding sustainable and economical solutions for the production system. The defense of a cyclical ecological system capable of reproducing new resources, building sustainable futures through the reuse and recycling of waste, producing new sources of energy and secondary materials, was initially discussed by economist Kenneth Boulding (1966) and resumed by Georgescu-Roegen (1971) and served as the basis for the ecological economics (Weetman, 2019).

In the following decade, Walter Stahel (1982) developed a "closed-loop" approach to production processes pursuing goals such as product life cycle extension, reconditioning activities and waste prevention. Subsequently, the definition of closed cycle was treated by the same author as Circular Economy (CE), in order to portray the idea that circularity in production systems causes positive effects such as resource efficiency, prevention and optimization of waste, an incentive to innovation and the creation of employment through the development of new business models (Stahel, 1982).

Other authors, such as David Pearce and Robert Turner (1990), highlighted the unsustainability of the linear and open-cycle economic system, in which the resources for production are extracted from nature, generating, as an output, waste that is disposed of in nature itself. As a solution, they advocated an economic system of closed-loop production capable of generating sustainability, maximizing the use of resources and reducing waste production, thus enhancing the economic value of the product (Weetman, 2019).

Michael Braungart and William McDonought (2010) developed the idea of Cradle to Cradle, which advocates that resources should be managed in a circular sense of creation and reuse, so that each stage of the cycle is a beginning for a certain material, a systematization for the generation of effective and regenerative industrial products and systems creating economic, social and ecological benefits (Gejer & Tennenbaum, 2017).

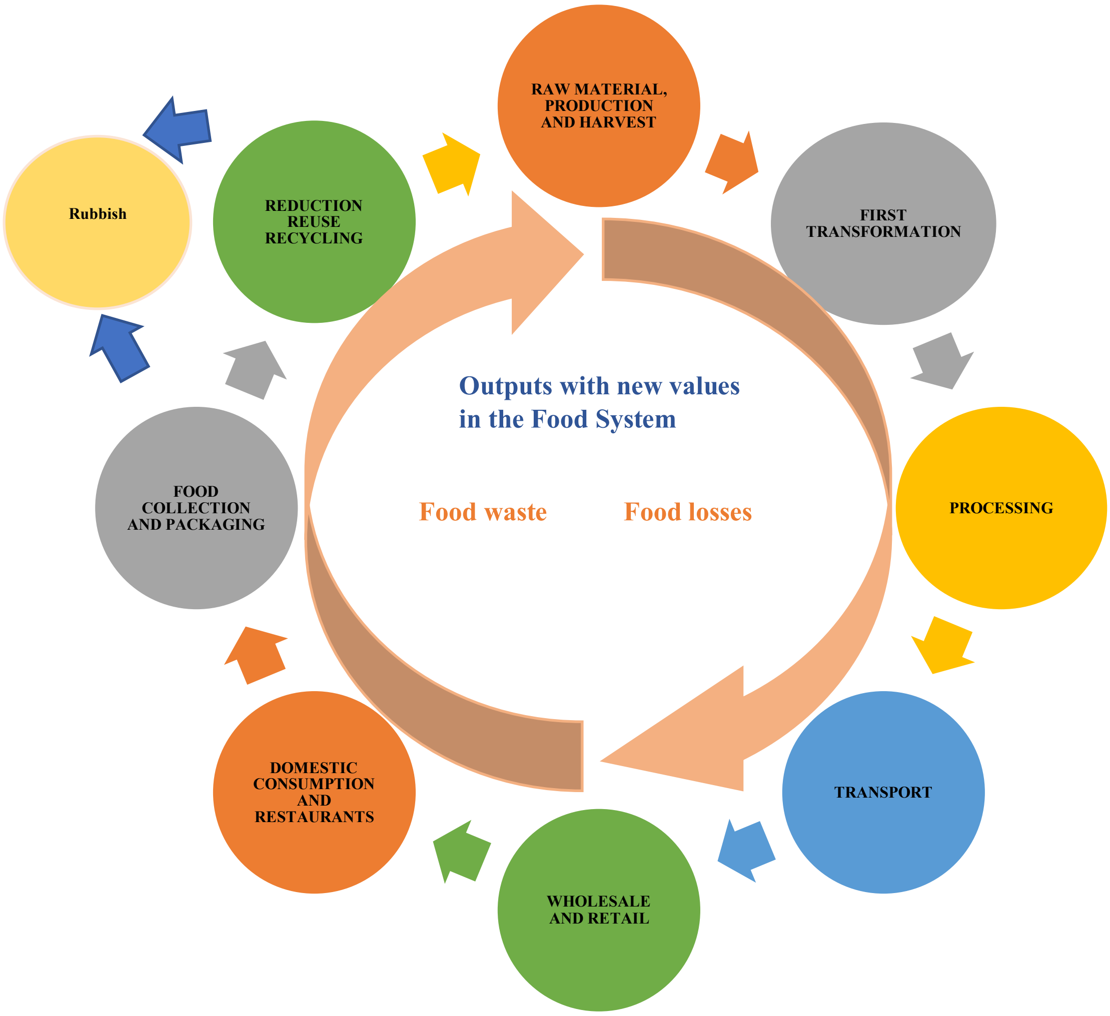
In this way, CE brings together approaches from different lines of thought that disseminate sustainability and the optimization of resources in the economic system. Among them, we can quote: Performance Economics, Industrial Ecology, Bioeconomy, Regenerative Design, Biomimetics and Blue Economy (Ellen Macarthur Foundation, 2017).

Therefore, CE is a production model that aims to dissociate economic activity from the consumption of finite resources and reduce waste generation from the beginning of the production system, in order to build economic, natural and social capital. It also brings another look at the idea of waste: what is discarded today and which is, most of the time, wasted, and should start to be reinserted in a new production cycle. Consequently, the rubbish discarded by a certain process serves as an input for another (Stahel, 2016).

CE requires economic activities according to the 3R principle, which are Reduce, Reuse and Recycle. Reduce the amount of inputs and waste generation from the beginning of the production process. Reuse is involved in extending the time intensity of the product and service (maximizing the product life cycle). Recycling focuses on regenerating renewable resources after use (Ellen MacArthur Foundation, 2017).

The CE model can be applied to all economic systems. Regarding the food system, the implementation of this model implies reducing the amount of waste, instituting the reuse of food, the use of by-products for organic compost, and the generation of energy through anaerobic digestion, as well as the reprocess for industrial use, among others. It therefore involves the entire food supply chain and promotes the interconnection between the sector (Fassio & Tecco, 2019). Figure 1 shows the interconnection within the food supply chain.

Figura 1 - Circular Economy applied to the food supply chain



Source: Created by the authors, adapted from Fassio & Tecco (2019).

As a model of production and consumption based on interconnection, CE revolves around a relationship among the flows of materials in sectors, in which the waste becomes "food", that is, an input for another process or product (Fassio & Tecco, 2019).

According to FAO, losses are incurred in the first stages: production, harvesting, transformation, processing and transport. Waste is more associated with commercialization and consumption (FAO, 2013). When they are able to be reinserted into the food system, the residues resulting from losses and waste come out with new value, as by-products for other processes, through reuse and recycling. When reuse is not possible, waste, in this case, the rejects, are discarded and they do not return to the system (Ellen MacArthur Foundation, 2017).

4 Food Losses and Waste

The concept of food loss refers to the decrease in the mass of food available for human consumption resulting from inefficiencies in the production chains that include the production, harvest, post-harvest, storage and transport phases. Food waste is related to the disposal of food, the intentional rejection of items by retailers and consumers, and is related to the behavior of companies or people in discarding food even when it is still fit for consumption (FAO, 2013).

FAO (2019) specifies that "losses" represent the total waste and that the disposal is only a part of the losses. Therefore, both the term "Food Loss" (FL) and "Food Loss and Waste" (FLW) can be used. This article uses the terms "food loss and waste" or "FLW" as equivalents.

FLW is a major global challenge from a social, environmental and economic point of view. First, because when faced with a state of food insecurity that affects about 24% of the world's population, it is regrettable that the total volume of FLW produced exceeds the capacity to supply the world's demand for food. An optimistic scenario of "zero waste", with efficient logistical distribution and fair prices, would serve most of the hungry population (FAO, 2020).

From an environmental point of view, the combat of FLW has become a public policy priority around the world in recent years. Food production involves intensive use of resources. This makes the food system one of the main propellers of climate change, due to the high degree of greenhouse gas emissions, in addition to the pollution of ecosystems through excessive inputs of fertilizers based on phosphorus and nitrogen (FAO, 2013).

The United Nations Convention on Climate Change proposed in 2015, in the Paris Agreement, to limit global warming to a level below 2°C, or preferably, to keep global warming until 2050, at a level of 1.5°C. estimates that by 2050, the environmental impacts of the food system could increase between 50% and 92% and reach levels that exceed the proposed limits for global planetary stability.

The authors carried out an analysis of predicted environmental impacts for the global food system, in a scenario designed for 2050, taking into account five types of environmental pressures: greenhouse gas emissions associated with agricultural production; land use for agricultural production; the consequences of land use associated with carbon or biodiversity losses; the demand for irrigation water and the contamination of soil and aquatic ecosystems due to the use of phosphorus and nitrogen-based fertilizers.

In this way, the study evaluated the effect of three possible interventions that could reduce these environmental pressures. The first concerns food consumption, through a change in diet that would limit meat consumption and prioritize plant-based foods, for example. Meat production generally requires a more intensive and environmentally damaging mode of production than is needed for plant-based foods. Therefore, greenhouse gas emissions from agriculture would not diminish unless the global meat consumption was reduced. (Springmann *et al*., 2018).

The second intervention that can reduce environmental impacts would be increasing the efficiency of food production through improvements in agricultural technologies and resource management, including the reuse of organic nutrients and water savings, among other measures. This would also make it possible to increase crop yields per unit of land. The third category that the authors considered concerns the reduction of food chain waste from production to consumption, which would increase availability without the need for extra food production (Springmann op. cit.).

"Ensuring sustainable consumption and production standards" is what defines the 12th target of the United Nations (UN) Sustainable Development Goals (SDGs), in which the item 12.3 refers to the waste of food to be minimized by half by 2030, considering the global food waste per capita at retail and consumption levels, in order to lessen FLW along supply chains (ONU, 2015).

According to FAO (2020), cereals, fruits and vegetables are the food groups responsible for the highest amount of FLW, with the consumption stage being responsible for the largest share of food waste for most food groups. Awareness of the sustainable consumption pattern is, in a way, a bold goal to achieve, because it depends, in many aspects, on the culture of a given consumer group (Caldeira, 2019).

In terms of production, innovations in product storage and packaging have been the reason for efforts and investment by several companies in the agri-food sector in order to extend the shelf life of food products and reduce FLW. One example is nano packaging capable of keeping food in ideal temperature conditions. However, the production of nano materials and other types of packaging implies new inputs of resources, generation of additional waste and, consequently, emissions of greenhouse gasses (Zhang *et al*., 2019).

With regard to economic aspects, FLW represents an inefficient use of scarce resources used for food production, such as land and water. In this way, the reduction of waste, in addition to contributing to the food challenge, allows the optimization of natural resources. On the other hand, the possibility of reusing the waste allows new inputs of by-products resulting from recycling, which grant the feedback of the production cycle in the agro-food system, as shown in Figure 1. Moreover, by dismissing FLW through these means, there is a gain in productivity in the agricultural sector, thus promoting economic growth (FAO, 2013).

4.1 Agri-Food Waste

The generation of waste and by-products is inherent to any productive sector. In the case of food production, they are enhanced by losses and waste. Inadequate final disposal of waste implies environmental pollution in addition to loss of biomass and nutrients. The increase in ecological awareness in recent years has begun the discussion of concepts of minimization, recovery, use of by-products and bioconversion of waste (EMBRAPA, 2017).

CE proposes the reduction and/or reuse of waste through physical, chemical and biological procedures that allow the treatment of organic waste. The main existing technologies for the recovery and treatment of organic waste are: recycling, composting, vermicomposting, biodigestion, incineration and landfill (Ellen MacArthur Foundation, 2017).

According to the Brazilian Agricultural Research Corporation (EMBRAPA), recycling is a process of transforming solid waste, and involves the alteration of the physical, chemical or biological properties, aiming at transforming it into inputs or new products. Vermicomposting is the process of biological transformation of organic waste, with the help of earthworms, which accelerate the decomposition process (EMBRAPA, 2017).

Biodigestion is the process of anaerobic digestion, capable of producing biogas. Incineration is a dry oxidation process at high temperatures, which reduces organic and combustible waste to inorganic matter, consequently reducing the weight and volume of waste (EMBRAPA, 2007).

The reuse of agro-food waste can be granted through reverse logistics within the distribution sector of the supply chain. The study by Fancello *et al.*, (2017) proposed a management system for the waste collection process resulting from the agribusiness distribution sector, in order to optimize the reuse of waste in all links of the chain, including grocery stores, supermarkets, farms, cattle raising and feed factories, in the province of Cagliari in Sardinia (Itália).

Although, in most countries, greater attention has been given to the management of waste resulting from FLW, in some countries, however, this discussion in the form of legislation has not yet been approved or has not entered into force. Mainly in developing countries, the management of agro-food waste lacks local administration systems (Li *et al*., 2016).

In Brazil, the PNRS aims to prevent and reduce the generation of waste, with a set of instruments to encourage recycling and the reuse of solid waste (Brasil, 2010). By incorporating economic value into what can be recycled or reused, the PNRS has mechanisms that go against the CE proposal.

Aspects of urban solid waste management, including agro-food waste, which is comprised in the PNRS, are spread to all over the government and the population in general. However, these aspects imposed on the municipalities the responsibility and effectiveness of dealing with management plans. This ends up compromising the implementation of the CE model, which requires the participation of all economic agents in public policy processes that directly involve the agro-food waste chain (Silva & Biernask, 2017).

5 Methodological Approaches to Quantify Food Loss and Waste

In order to define a methodology on food waste, it is necessary to define it, then measure and quantify it. The English organization Waste and Resources Action Programme (WRAP)[1] has classified the various types of waste and stipulated the definitions as (WRI, 2016):

a) Avoidable food waste: food and beverages that are in perfect condition to be consumed, but end up being rejected and discarded;
b) Potentially preventable (possibly avoidable) food waste: foods and drinks that some people eat and others don't (eg. bread edges), or that can be ingested when prepared in a specific way (eg. potato skins). This avoidable fraction is made up of materials that are edible; and
c) Unavoidable Waste: Waste from food and drink that is not edible under normal circumstances (eg. bones, skin and eggshells).

However, this classification leaves doubts between what is and what is not avoidable, since different cultures in each region of the world prepare their food in different ways, which will influence the classification regarding the types of waste (Corrado *et al*., 2017). The disposal decision is very subjective, personal, and is governed by culinary, nutritional knowledge, and acquired habits. For this reason, there is a middle term called "possibly avoidable"; however, the opinion of who will classify the waste is subjective and therefore questionable (Creus, 2018).

5.1 The Food Loss and Waste Accounting and Reporting Standard (FLW Standard).

Developed by the Waste & Resources Action Programme, the Food Loss and Waste Accounting and Reporting Standard (FLW Standard) is intended to facilitate the measurement and to encourage consistency and transparency of data (WRI, 2016). The standard allows quantification and tracking towards the 12.3 Goal[2] of the United Nations Sustainable Development Goals. WRI Brasil[3] has been the main proposer of the FLW Standard in Brazil. The measurement of waste can be done through:

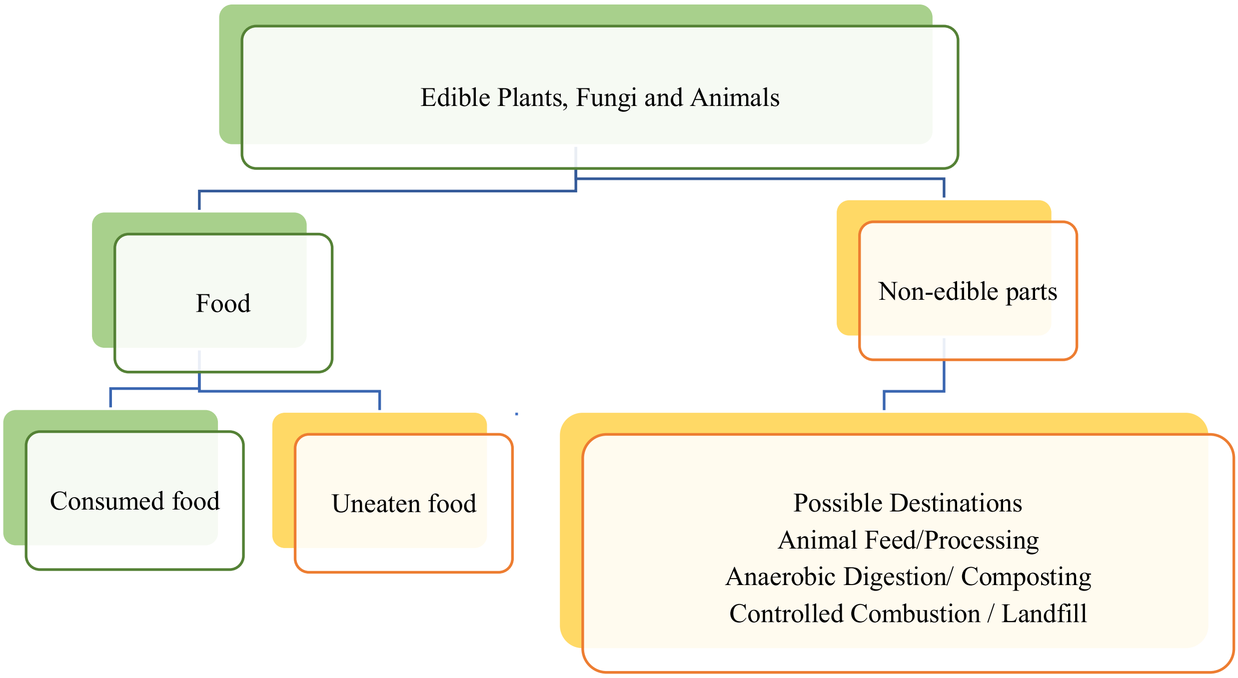
a) Direct weighing: using a scale or a specific device to measure the weight (mass) of the products;
b) Count: evaluate the number of items that make up the losses and waste of the FV and use the FLW result to determine the weight. This analysis includes the use of data from scanners and scales;
c) Evaluation by volume: evaluation of the physical space occupied by the losses to determine their weight;
d) Waste composition analysis: separating FV losses from other items to determine the weight of generated waste;

[1] *Waste & Resources Action Programme*: is an NGO that works with businesses, individuals and communities to achieve CE by helping them to reduce waste, develop sustainable and resource-efficient products.
[2] 12.3 Goal: By 2030, halve per capita global food waste at retail and consumer levels, reduce food losses along production and supply chains, including post-harvest losses (ONU, 2015).
[3] WRI Brasil is part of the World Resources Institute (WRI), a global research institution operating in over 60 countries.

e) Miscellaneous records: data that have been written or saved, and which are often collected for other reasons to quantify losses, such as transfer receipts from warehouse register books;
f) Daily journaling: keeping daily records of losses and other information;
g) Surveys: collection of FV losses data, considering beliefs, habits, consumption behaviors among others through a set of questions, for a group of individuals;
h) Mass balance: using input data and product output data, in order to evaluate mass gains or losses to determine food losses;
i) Modeling: using a mathematical method with an approach based on the interaction of multiple factors that influence the generation of FV losses and waste; and
j) Proxies: using FV loss data that is outside the scope of a property or company's loss inventory (e.g. older data, loss data from other countries or companies) to infer amounts of losses within the scope of the property's inventory.

Consumed food is food that at some point in the food supply chain, including surplus food, is redistributed to people and consumed. Uneaten food and non-edible parts represent the two possible types of material in a FLW inventory, which go to one or more possible destinations once they are removed from the food supply chain (Figure 2).

Figure 2 - Types of materials and possible destinations according to the FLW Standard



Source: Elaborated by the authors. Adapted from WRI (2016)

According to the FLW Standard, the destination of food waste may be used in animal feed or as a natural base input for further processing. Plants, fungi and animals are, in this model, intended for human consumption, which means that this excludes crops intentionally grown for bioenergy, animal feed, seeds or industrial use.

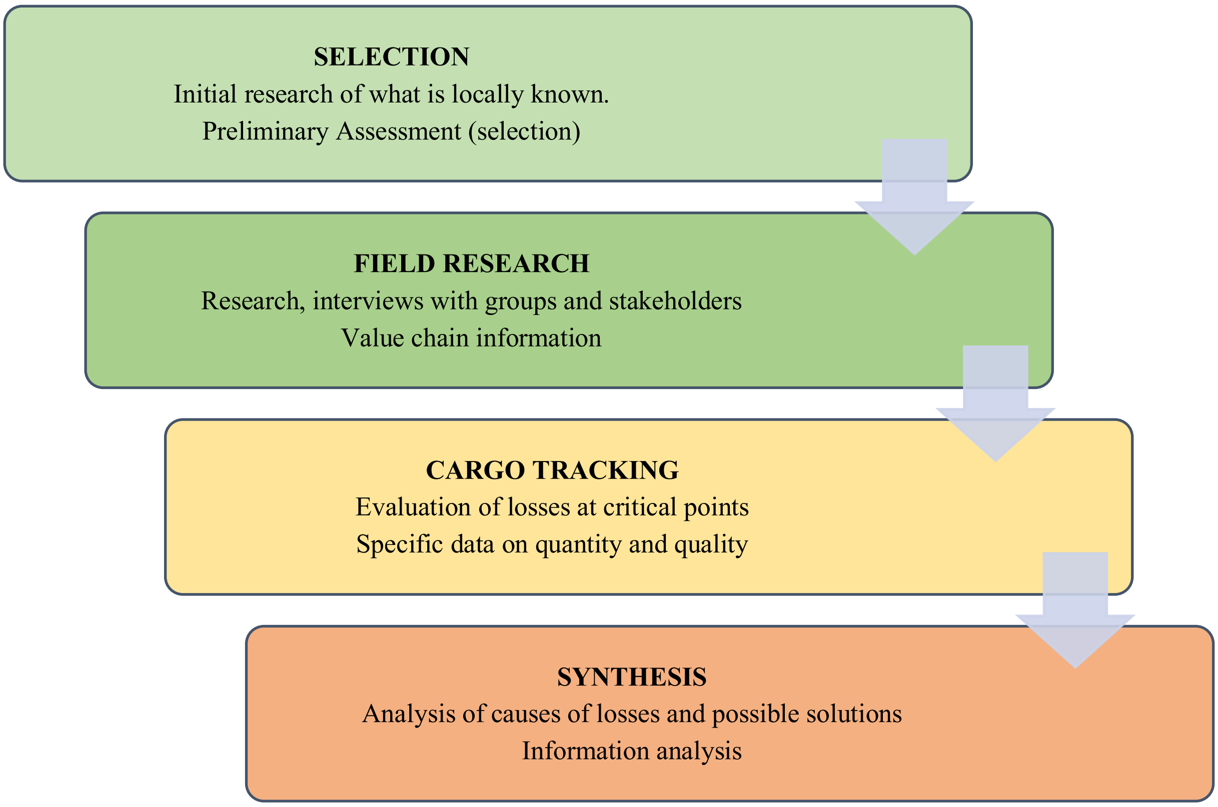
5.2 FAO Methodology

FAO's methodology aims to promote an understanding of the main causes of food losses and the impact of possible solutions with respect to the technical and economic viability of the food sector, in order to ensure food security, social acceptability and environmental sustainability (FAO, 2020).

The main unit of analysis taken into account by the FAO methodology is the supply chain which is studied within geographic boundaries from production to retail. The objective is to identify critical loss points along the Food Supply Chain (FSC) and assess the impact on food security and economic dimensions and propose the formulation of public policies with programs to reduce food loss.

The framework of the methodology includes four viable tools for rural infrastructure and agro-industries. Figure 3 contains an overview of the FAO structure and the links between these tools.

Figure 3 - FAO methodology for FLW analysis



Source: Elaborated by the authors. Adapted from FAO (2020).

Firstly, a selection is carried out in order to overview the sector and select the main issues in the supply chain, by identifying the main source of losses and the critical points on which to focus when continuing with the next steps of the evaluation.

Next, a research is carried out in the field, through questionnaires and surveys to be carried out with the different actors in the selected supply chain. The scope of this phase is to have a clear idea of the product flow, and to identify where the food loss occurs.

The third step is the evaluation of cargo tracking and sampling. Finally, a synthesis is made, with the aim of finding a solution by developing intervention proposals for food losses based on the results of the previous evaluation stages (FAO, 2020).

5.3 European Union methodology based on the FUSION Project

The European Commission adopted the methodology of the FUSION project (a manual, in accordance with the FLW standard) to define an identification strategy and sustainable targets in the fight against FLW at different stages of the supply chain (Garcia *et al.*, 2016)

The methodology proposes to achieve a reduction (by weight) in the amount of food waste through preventive actions that can be implemented. The loss prevention action can be applied according to the stage at which the waste occurs, from production to the consumer (Priefer, Jörissen, & Bräutigam, 2016):

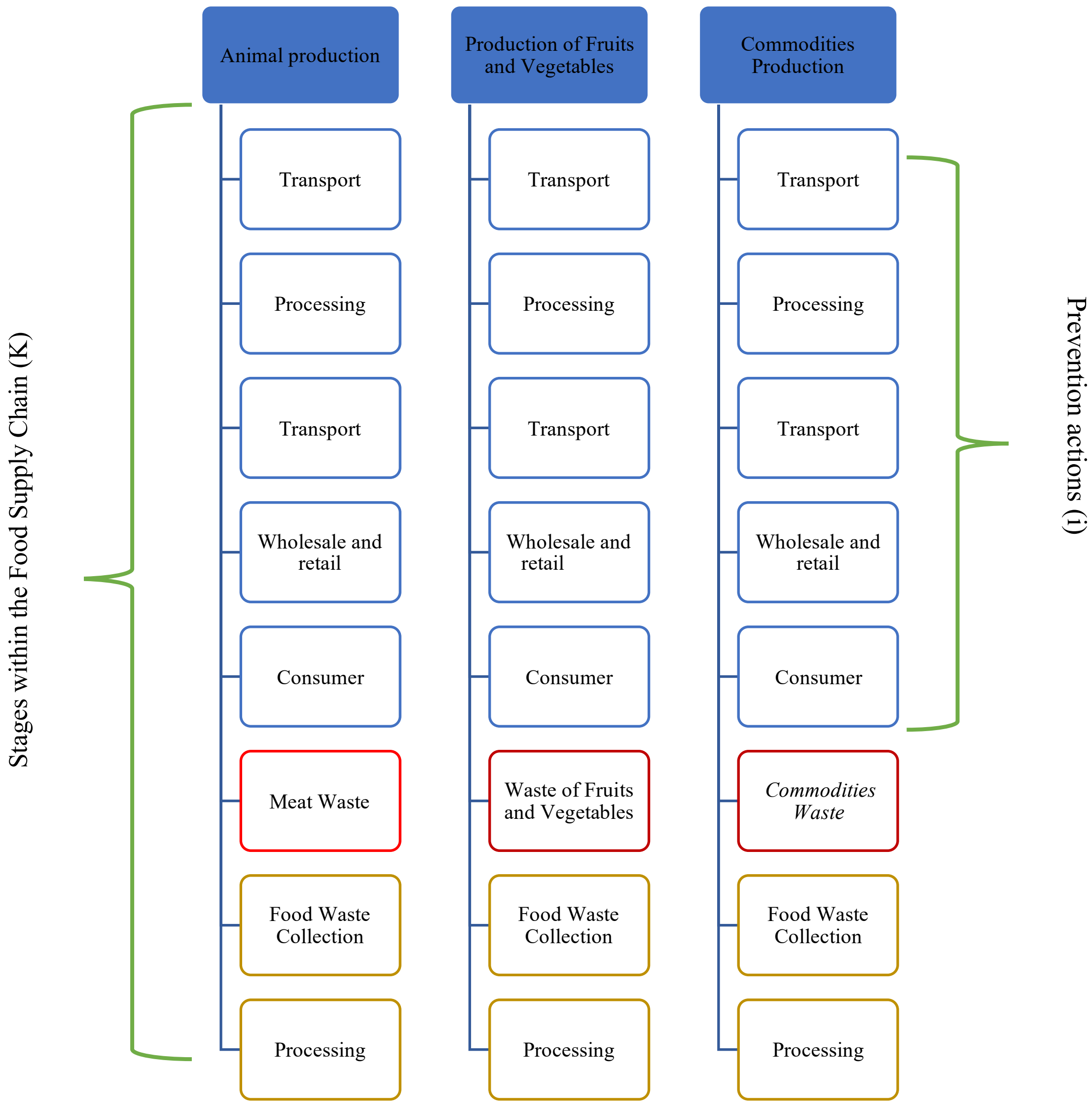
In production, the encouragement of non-marketable food donation, the improval of the availability of agricultural extension services and harvesting techniques, and the support of the market access; in transport, the aim of storing with technologies and investment in infrastructure to access roads, railways and ports;

In processing and packaging, the re-engineering manufacturing and packaging processes to keep food fresher for longer; in wholesale and retail, the simplification of unsold goods donation, promotions of items close to expiration date and improvements in inventory systems;

Carry out consumer education campaigns, promote the donation of unsold products from restaurants and suppliers, reduce portion sizes and ensure home economics is taught in schools, colleges and communities (Priefer, Jörissen, & Bräutigam, 2016).

Figure 4 shows three food supply chains (FSC): Animal Production, responsible for supplying meat, skin and milk; Production of Fruits and Vegetables and Production of Commodities. In each FSC it is possible to verify stages (k) where the loss prevention action (i) can be applied.

Figure 4 -Different Food Supply Chains (FSC) and stages where prevention action can be applied



Source: Elaborated by the authors. Adapted from GARCIA *et al.*, (2016)

However, to calculate the efficiency of preventive actions, it is necessary to know the amount of food waste generated, the percentage of avoidable and possibly avoidable food waste.

The methodology addresses the assessment of amounts of food waste as a result of the implementation of one or more actions. For this, the types of prevention (potential and real) are defined, delimiting the scope and factors of participation within the stages. The variables used in this model are: Food Supply Chain (FSC); Quantitative result (Q); Prevention action (i); Stage of the food supply chain (k) (Garcia *et al.*, 2016).

In order to assess the quantitative result (Q) of different actions (i) at the boundaries of the food system, it is necessary to differentiate $Qgenerated_j$, $Qpotential_{i,j}$ e $Qprevented_{i,j}$. hey are all related to a specific food supply chain (FSC) (j) and can be divided into each stage (k) from FSC: ($Qgenerated_{j,k}$, $Qpotential_{i,j,k=p}$, $Qprevented_{i,j,k=p}$).

They are always expressed in tons of food waste. Only $Qpotential_{i,j,k=p}$, $Qprevented_{i,j,k=p}$ occur at a certain stage of $CSA_{k=p}$, where a specific waste prevention (i) action is implemented (Garcia *et al.*, 2016).

$Qgenerated_j$ is the total food waste generated in a FSC_j by a specific target group. It includes all types of food waste: edible and inedible, avoidable, possibly avoidable and unavoidable food waste. It can be calculated from the relative $Qgenerated_j$ expressed in kg per capita (Equation 1).

$$Qgenerated_j = Qgenerated_j * number\ of\ inhabitants \quad (1)$$

Where,
$Qgenerated_j$ is the total food waste generated in a Food Supply Chain (FSC);
j is a specific target group where a prevention action is implemented;
Number of inhabitants refers to participants in the prevention action.

The total amount of potentially avoidable food waste ($Qpotential_{i,j}$) in a FSC_j when the action (i) is done, corresponds to the sum of the avoidable factors and possibly avoidable parts of food waste. $Qpotential_{i,j}$ can also be calculated from the relative $qpotential_{i,j}$ (eg. kg per capita).

The total amount of food waste that can actually be avoided ($Qprevented_{i,j}$) when action (i) is applied. It corresponds to the part of $Qpotential_{i,j}$ that each target group participated and applied actions to avoid waste. It can also be calculated from the relative $qprevented_{,j}$ eg. kg per capita).

Therefore,

$$Qprevented_{i,j} \leq Qpotential \leq Qgenerated$$

To calculate the final amount of potentially or actually avoidable food waste, two other factors need to be taken into account:

a) The absolute amount potentially or effectively avoided depends on the scope of the action objective compared to the size of the system. For actions targeting citizens, for example, is the total population of the area. *S* therefore defines the target group as a percentage of the total potential target.
b) The participation rate ($P,\ 0 < P < 1$) defines the target group users who effectively participate in the action. This means that the total potential amount (Equation 2 and 4) and actually avoided (Equation 3 and 5) can be calculated with the following equations, depending on the available data:

If total quantities expressed in tonnes are given:

$$Qpotential_{i,j} = Qgenerated_j * S \quad (2)$$

$$Qprevented_{i,j} = Qpotential_{i,j} * P \quad (3)$$

In which,
$Qpotential$ is the total amount of food waste that can potentially be avoided in a supply chain (FSC);
$Qgenerated_j$ is the total food waste generated in a Food Supply Chain (FSC);
$Qprevented$ s the total amount of food waste that can actually be avoided when the prevention action (i) is implemented;
j is a specific group or target where a prevention action is implemented;
i refers to the prevention action;
S is the scope factor, percentage achieved of the total potential target. ($S,\ 0 < S < 1$); and
P refers to the percentage of those who effectively participate in the action. ($P,\ 0 < P < 1$).

If relative data expressed in kg per capita are provided:

$$Qpotential_{i,j} = qpotential_{i,j} * number\ of\ inhabitants\ *S \quad (4)$$

$$Qprevented_{i,j} = qpotential_{i,j} * number\ of\ inhabitants\ * S\ *P \quad (5)$$

In which,
Qpotential is the total amount of food waste that can potentially be avoided in a supply chain (FSC);
$qpotential_i$ is the relative amount, in per capita terms, of food waste that can potentially be avoided;
Qprevented is the total amount of food waste that can actually be avoided when the prevention action (*i*) is implemented;
$_j$ is a specific group or target where a prevention action is implemented;
$_i$ refers to the prevention action; and
S is the scope factor, a percentage achieved of the total potential target. ($S,\ 0 < S < 1$);
Number of inhabitants refers to participants in the prevention action.

Understanding the scope and factors for action and participation are important to help decision makers understand about the type of strategies to be developed (voluntary, mandatory or other). The choice of these factors also reflects the participants' level of engagement to reduce food waste and to reach the proposed goal (Garcia *et al*., 2016).

5.4 Food Recovery Hierarchy (FRH)

The European Union (EU) Waste Framework Directive (WFD) establishes priorities regarding the reuse of food waste. According to the Food Recovery Hierarchy (FRH) methodology, the first option in the recovery hierarchy is waste prevention and reduction, which includes a set of measures taken before a product is discarded (CE, 2008).

After that, it is necessary to take enough care during the preparation for reuse, including control, cleaning or repair operations to make reuse feasible. The Directive encourages recycling in any recovery operation through the reprocessing of waste into new products, and establishes disposal when the recovery operation is not possible. In this case, the processes for waste disposal are landfill and incineration.

The United States of America Environmental Protection Agency (US EPA), adapted the Food Recovery Hierarchy (FRH) shown in Figure 5, composed of six levels that prioritize actions that individuals and organizations can take to reduce waste and recover food (US EPA, 2018).

The 1st level of the FRH refers to the reduction of food waste directly at the source, adapting food production and processing methods and awareness of consumer habits and behavior. According to the CE concept, the reduction of waste from the production until the final consumer contributes to decreasing the use of natural resources in addition to reducing waste Generation.

The 2nd level refers to the reuse of waste for human consumption: the aim is the donation of surplus food from commercial establishments. This ensures food security for needy populations.

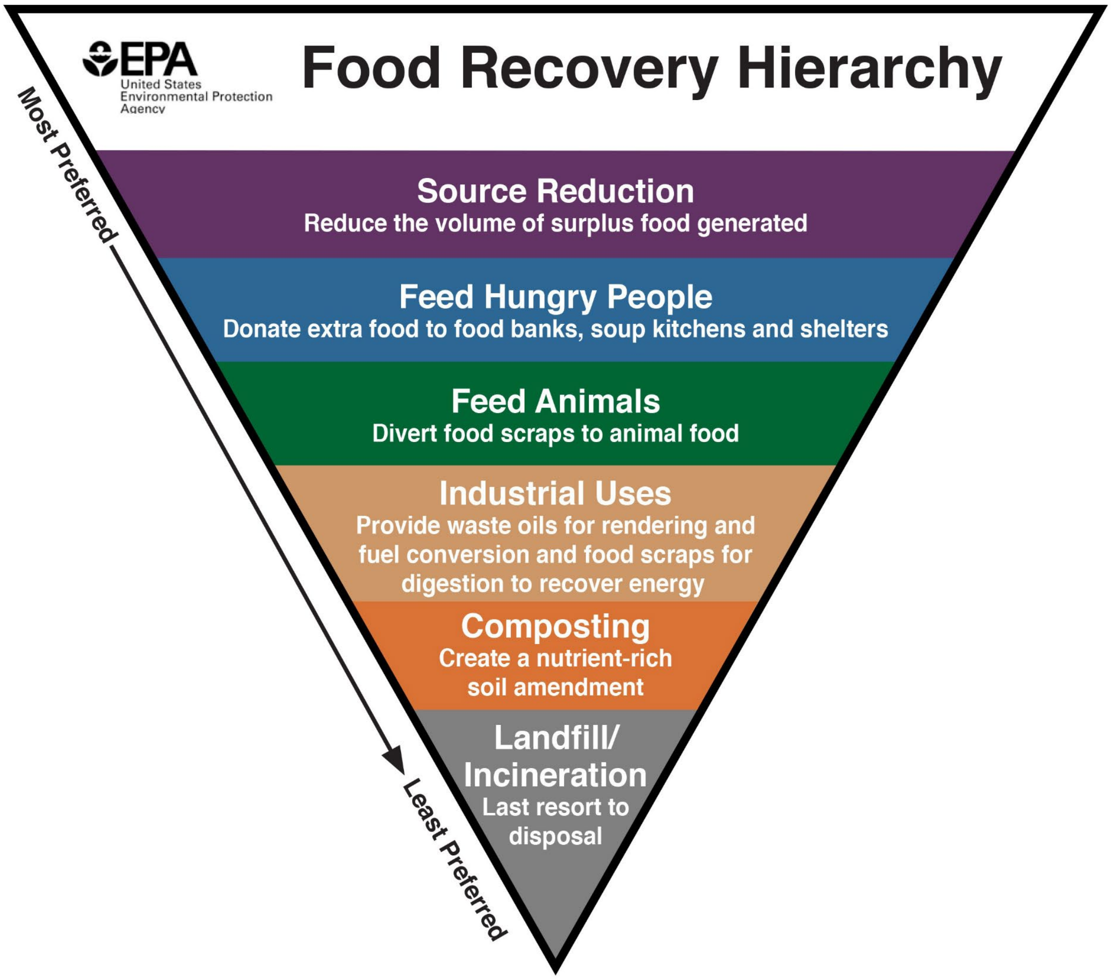
The 3rd level includes options for reusing waste for animal consumption, which can be used as inputs in feed production.

The 4th level refers to industrial recycling, increasing the use of alternative energy sources, such as energy production (biogas and biodiesel).

The 5th level refers to the composting process available to everyone, from individuals to organizations, in order to produce quality organic fertilizer that returns to the food production cycle.

The 6th level refers to waste that cannot be reused, requiring incineration or deposit in landfills.

Figure 5 - Food Recovery Hierarchy (FRH)



Source: US EPA (2018)

Each level of the Food Recovery Hierarchy focuses on different management strategies, and prioritizes actions that organizations can take to prevent and repurpose lost food. When it comes to food waste, some actions can be proposed to avoid the generation of waste. With regard to recycling, measures such as anaerobic digestion, employs the compost as a natural fertilizer. Moreover, biogas and even the burning of waste can be used for energy; and, finally, disposal in landfills or burning without energy use can be performed for irrecoverable waste (US EPA, 2018).

6 Final Remarks

CE translates into a new way of systematically thinking about the economic system, aiming to transform the current model of production and consumption, in order to achieve a balance among economy, environment and society.

In this sense, discussing the issue of FLW from the point of view of the main quantification methodologies, contributes to addressing the issue of losses and waste, pointing out ways to reduce and reuse waste for economic purposes, such as the production of renewable energy, organic inputs and new entries of value in the supply chain, as well as social purposes, through food donation.

With regard to adherence to CE concepts, the FLW quantification methodologies address issues related to CE and consider the three dimensions of sustainability (environmental, economic and social). Combating FLW contributes to reducing the use of natural resources used in food production, in addition to minimizing waste generation and promoting food safety.

The measurement methods presented by the FLW Standard developed by the Waste & Resources Action Program facilitate the construction of the FLW inventory composition through the quantification and monitoring of waste. Measuring FLW is of paramount importance for setting goals, both at the micro and macroeconomic levels. By directing the possible destinations of uneaten food and inedible parts of food, this contributes to combating food waste and reducing losses. Consequently, the reuse of waste is proposed.

The European Union Methodology based on the Fusion Project brings the possibility of implementing and monitoring prevention actions directed at specific stages in the food supply chain where waste occurs. FAO emphasizes the importance of identifying the critical points of loss and a detailed analysis through screening, research, cargo tracking, among others, in order to obtain accurate information about the causes of waste and, in this way, propose possible solutions to the problem.

The Food Recovery Hierarchy (FRH) is a methodology that delimits priority levels in the recovery of food waste, ranging from reducing waste directly at the source, to different reuse alternatives.

Therefore, CE precepts are met in all methodologies presented, which close the agro-food production cycle, generate sustainability and maximize the use of resources. The combat of waste favors the reduction of natural resources used in food production, the reuse of agro-food waste as by-products, which add value to something that would otherwise be discarded and reduce production costs by being reinserted into the food supply chain.

With regard to the Brazilian scenario, it is important to create, in local governments, a mechanism for accessing information related to waste, the integration of the FSC can contribute to the dissemination of this data. An example of public policy, in this sense, is the promotion of connections among food producers, agro-industrial establishments, distributors (wholesale and retail), which are part of the production chain), administrations, agencies and other public authorities, including the consumer.

To this end, it is necessary to implement legal instruments that reduce marketing gaps through planning, starting from the conception of products, the entire marketing and use process and the propagation of the culture of conscious consumption, so that the prevention results are effective.

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