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Waste in Agri-Food Chains in the Context of the Circular Economy

Desperdício nas Cadeias Agroalimentares no Contexto da Economia Circular

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Resumo
O objetivo deste trabalho foi compreender o estado da arte na Economia Circular (EC) do desperdício de alimentos, por meio de revisão da literatura internacional. Para o levantamento das informações, foi utilizada a técnica da revisão sistemática de literatura (RSL), fundamentada no protocolo de Cronin, Ryan e Coughlan (2008), utilizando o recorte temporal dos últimos dez anos, 2010 a 2020. Esta RSL foi realizada em cinco bases: Web of Science, Scopus, Science Direct, Taylor e Francis e Emerald. As etapas foram descritas e, ao final, foram analisados 50 artigos. Os resultados apontam para um crescente interesse dos pesquisadores, principalmente na Europa, focados em tentativas de implementar modelos circulares que visem mitigar o desperdício alimentar, e que a transição para esses modelos é essencial devido ao esgotamento dos recursos naturais e externalidades socioeconômicas negativas. Tais resultados lançam luz a novas possibilidades de pesquisa e a políticas públicas para redução de desperdício que certamente engendrarão ganhos econômico, social e ambiental no contexto dos países em desenvolvimento. Por fim, sugere-se uma agenda de pesquisa para avanços de estudos na temática.
Palavras-chave: Economia Circular. Desperdício de alimentos. Sustentabilidade.

Abstract
The objective of this paper was to understand the state of the art in the Circular Economy (CE) of food waste through a review of international literature. The systematic literature review (SLR) technique, based on Cronin, Ryan and Coughlan (2008) protocol, was used to gather information, using the time clipping of the last ten years, 2010 to 2020. We performed the SLR on five bases: Web of Science, Scopus, Science Direct, Taylor and Francis and Emerald. We described the steps and, in the end, we analyzed 50 papers. The results point to a growing interest of researchers, mainly in Europe, focused on attempts to implement circular models aimed at mitigating food waste and the transition to these models is essential due to the depletion of natural resources and negative socio-economic externalities. It is noteworthy that this research can bring economic, social and environmental gains in the context of developing countries. Finally, we suggest a research agenda for the advancement of studies on the subject.
Keywords: Circular Economy. Food Waste. Sustainability.

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1 INTRODUCTION

The world needs food to meet human needs. The reuse of food waste, transforming it into other value-added products, has received special attention in recent decades, notably because of the benefits it brings to business and society. In food supply chains (CSAs), extending the shelf life of consumable food products is a necessity to mitigate food waste problems. There are about 366,000 tons of food waste per year in the different stages of retail distribution, and this means that every day the food chains lose large amounts of food products (FRANCELLO *et al*., 2017).

In this context, several developed countries have implemented the principles of circular economy (CE) in their public policies to mitigate the problems of food waste and safeguard natural resources that are becoming increasingly scarce. This was the case of Japan, China, Holland and Germany, countries most involved with circular techniques (LEMOS, 2018).

However, in the article by Sheppard *et al*. (2020), tools that incorporate a logic model were developed in order to identify and quantify food waste streams at different scales. These tools for converting food waste into other raw materials have proven effective, but not sufficient to ensure the management of food waste at a suboptimal level.

Slorach *et al*. (2020) analyze possible future scenarios for the management of food waste. For them, any commitments to improve the sustainability of food waste treatment must be accompanied by an effective waste prevention strategy.

Nanopackaging has proven to be a promising technology to significantly extend the shelf life of food products and a potential solution to reduce the source of food waste. However, the production of nanomaterials requires input of extra resources and generates additional emissions and waste (ZHANG *et al*., 2019).

On the other hand, scholars point to the need to use quantification techniques to reduce food waste in agrifood supply chains, particularly milk value chains (WESANA *et al*., 2019).

However, for studies that quantify these losses to be effectively interpreted, it is necessary to standardize the methods used for this purpose. Thus, a lack of studies adopt a systematic approach to account for food waste, providing values disaggregated by stages of the food supply chain and by food groups (CALDEIRA *et al*., 2019).

However, some studies have focused on reducing food losses and waste. For example, Santos, Guimarães and Junior (2019) examined engagement strategies to deal with food waste in hospitals. Deliberator (2019) examined food waste in Brazilian university restaurants. Creus (2018), in turn, worked on quantifying food waste in Brazil.

Liu *et al*. (2020) studied the characterization of the environmental impacts of packaging waste generated by urban food delivery services in China. Dhir *et al*. (2020) analyzed the impacts of food waste on hotel services. Santos *et al*. (2020) discussed the different legislations in force, which are ready to be implemented in Brazil to prevent and reduce food waste. Moraes *et al*. (2020) carried out a systematic review of the literature that maps the causes of food waste and reduction practices in a broader context of the supply chain, particularly in retailers. Dora *et al*. (2021) carried out a systematic review of the literature over the last 20 years on food waste in the supply chain in developed and less developed countries. Annosi *et al*. (2021) addressed digitization within food supply chains to prevent food waste.

Thus, some studies address specific sectors of food loss and waste Dhir *et al*. (2020) and studies reporting the concept of CE (GHISELLINI *et al*., 2016; KORHONEN *et al*., 2018; MERLI *et al*., 2018). On the other hand, there are few publications on food waste from the perspective of the circular economy (CE). This fact occurs because it is associated with a variety of academic concepts such as cradle to cradle, industrial ecology,

industrial symbiosis, closed supply chains, among others, and it still lacks theoretical consolidation. In addition, the CE is linked to the concept of sustainable development, pointing out various forms of its operationalization at the micro, meso and macro levels (GHISELLINI *et al*., 2016).

Therefore, our study aims to understand state of the art regarding food waste from the perspective of CE, through a systematic review of the international literature, based on the protocol by Cronin, Ryan and Couglan (2008), whose inclusion criteria and exclusion were defined in the methods section.

Through this study, policymakers can learn lessons on how to add value from reducing food waste to help and guide actors in the food supply chain to benefit from a circular food system. Researchers working in the field can also obtain data that indicate possibilities for future studies.

2.1 Circular economy

CE sector initiatives in developed countries, such as the United States of America, Japan and Europe, have stood out concerning to waste management (LUTTENBERGER, 2020). Furthermore, new innovative CE initiatives are encouraged by empowering people for collaborative efforts (LEVOSO *et al*., 2020).

The 3R model (Reduce, Reuse, Recycle) has been considered the guiding source of CE in several studies worldwide (KRISTENSEN; MOSGAARD, 2020). In the reduction process, the minimization of inputs through better eco-efficiency and consumption standards results in the use of fewer raw materials, non-renewable energy and waste production (SU *et al*., 2013). The reuse process is profitable for producers, consumers and environmentalists, as it requires limited resources, such as labour and energy, compared to the manufacture of new products with virgin materials (CASTELLANI *et al*., 2015).

The recycling process allows the extraction of reusable material from waste generated at the end of the product's life cycle, reducing its environmental impact (JABBOUR *et al*., 2019). It is considered parallel to the CE model, as it has the potential to reduce waste to zero (SONG *et al*., 2015). However, recycling has the opposite effect to reduction and reuse processes in terms of resource efficiency and environmental sustainability (GHISELLINI *et al*., 2016).

The CE aims at source reduction, from the project that foresees the dismantling, use of more sustainable materials, including those that are biodegradable or that serve as raw material for the same or other production processes. Many countries, especially those in development, still focus on recycling as the main means to make the transition from the CE viable, but the correct thing is to also reduce inputs from the planning stage, eliminating waste from this process, which are those for which there is no technology. or economic feasibility for recycling (GUARNIERI; CERQUEIRA-STREIT; BATISTA, 2020).

CE aims at the relentless pursuit of waste disposal. It emerges as a sustainable, regenerative and restorative development model, whose objective is to maintain products, food residues and natural resources at their highest level of utility and value over time, generating social, economic and environmental benefits for society (ELLEN MacARTHUR FOUNDATION, 2015). CE is an industrial system that aims to replace the end-of-life concept of products through a closed loop. From the CE, it is possible to eliminate the use of toxic products that harm the biosphere and residues. The scope of the CE is the reduction of waste, raw materials and non-renewable products through closed production systems and new business models (EMF, 2014).

However, there is no consensus on the origin of EC. Some authors point out that EC has its origins in the literature on

economics (BOULDING, 1966; PEARCE; TURNER, 1990), industrial ecology (FROSCH; GALLOPOULOS, 1989; LIFSET; BOONS, 2012) and corporate sustainability (LOVINS *et al*, 1999; BENYUS, 2002; MCDONOUGH; BRAUNGART, 2002; STAHEL, 2016; GUIDE; VAN WASSENHOVE, 2009; PAULI, 2010; MURRAY *et al*., 2015), whose concepts began to impact the academic, business and industrial communities.

The understanding of CE and its applications in the current economic system and industrial processes have advanced and incorporated different concepts that share the idea of closed cycles (GEISSDOERFER *et al*., 2017).

For Andersen (2007), Ghisellini *et al*. (2016), Lieder and Rashid (2016) and Su, Heshmati, Geng and Yu (2013), CE has received significant attention in academic research and circular product design (BAKKER *et al*., 2014). Ellen Foundation MacArthur's work in the European Union in relation to the benefits of the EC for the environment since 2010 has been essential and has caught the attention of stakeholders and policymakers, influencing governments and intergovernmental agencies at local, regional, national and international levels (GEISSDOERFER *et al*., 2017).

Thus, the CE was perceived as a systemic and multi-stakeholder approach in a value chain, life cycle, innovation, and transformation towards sustainable development, reconciling different interests. Furthermore, it goes far beyond recycling and waste management. This new paradigm takes into account the useful life of products, materials and natural resources used in production, transport and consumption. Furthermore, the transition to a CE involves the most efficient use of resources along the supply chain and consumption processes (SAUVÉ *et al*., 2016).

Thus, the management of food waste within the CE can be observed in several aspects according to the recovery and recovery models of the latter. Following this logic, measures for the treatment, measurement and control of the food waste generated are essential. In addition, food waste must be valued with a view to social, economic and environmental results (UNGER; RAZZA, 2018).

2.2 Food waste

Some studies distinguish unavoidable, potentially avoidable and preventable waste (*WASTE AND RESOURCES ACTION PROGRAMME,* 2009) and consider avoidable waste only as waste, while other studies do not make this distinction (ÖSTERGREN *et al*., 2014).

Thus, the difficulty comes from the use of the word "loss" for certain actors (agriculture, industry, agrifood) and the word "waste" for consumers, retailers, wholesalers, and actors in short chains such as fairs. The term "waste" is more negatively connoted than the term "loss" and implies, in particular, a specific responsibility/responsibility of the one who wasted the food. The two expressions (loss and waste) do not have an equivalent vocabulary and are literally interchangeable. For example, the English word *waste* means both (waste, waste, loss / waste, rubbish, sewage, dump), depending on the context. The term waste can be translated in English as *waste, wastefulness, wastage, squandering...* while the word *wastage* in English, can be translated as waste or loss (LE BORGNE, 2015).

Studies by Kinobe *et al*. (2015) in Uganda show that of the products delivered to landfills, food waste made up the most significant amount (39%), followed by plant products (23%). The possible products recovered from landfills are: plastics, polyethylene, soft, textiles, paper and metal with the respective percentages: 31%, 37%, 15%, 12% and 5%.

According to data recorded by the *Food and Agriculture Organization of the United Nations* (FAO, 2018), about one-third of the food produced in Europe is

wasted. The global costs of food waste exceed $1.7 million per year. According to FAO, consumers are responsible for 52% of waste, retailers for 9%, the processing industry for 17%, and the producing industry for 23%.

Considering the above, regarding the reduction of food waste in the world, studies have focused on the quantification and causes of food waste in different production chains. For example, Parfitt *et al*. (2010) conducted a literature review on quantifying food waste in global food supply chains, while other authors focused on specific countries, such as Switzerland (BERETTA *et al*., 2013), Pakistan (TOSTIVINT *et al*., 2017), the United States, the United Kingdom, France (MENA *et al*., 2014; Mourad, 2016), Canada (DELORENZO *et al*., 2019), and Western European countries (TELLER *et al*., 2018). In contrast, few studies are conducted in developing countries, which is a gap in the literature that the present review sought to fill (DORA *et al*., 2021).

3 Research methods and techniques

This is a research of an applied nature, since the objectives are exploratory-descriptive, with a qualitative approach. As for the technical procedure of the research, literature review was used. It is important to note that there are also two types of literature review, as emphasized by Cronin, Ryan, and Coughlan. (2008): traditional or narrative literature review and systematic literature review (SLR). The traditional review does not make explicit the procedures used to select and filter the articles, and has greater subjectivity in the researcher's choices. On the other hand, SLR uses a more rigorous and defined approach to review the literature, making explicit the inclusion, exclusion and filtering criteria of the articles, therefore, it provides the critical analysis of the published articles of the study area in question and the authors of the article itself, to ensure its robustness and replicability (CRONIN, RYAN and COUGHLAN, 2008).

Therefore, the preparation of a script/protocol for article selection is necessary to demonstrate the existing gap in the scope of the defined research intent. For this purpose, the Cronin, Ryan, and Coughlan (2008) Protocol was used, a procedure consisting of five steps, namely 1. formulation of the research question; 2. establishment of a set of inclusion and exclusion criteria; 3. selection and access to the literature; 4. assessment of the quality of the literature included in the review; 5. analysis, synthesis, and dissemination of the results, described in Table 1.

Table1-Steps of the research

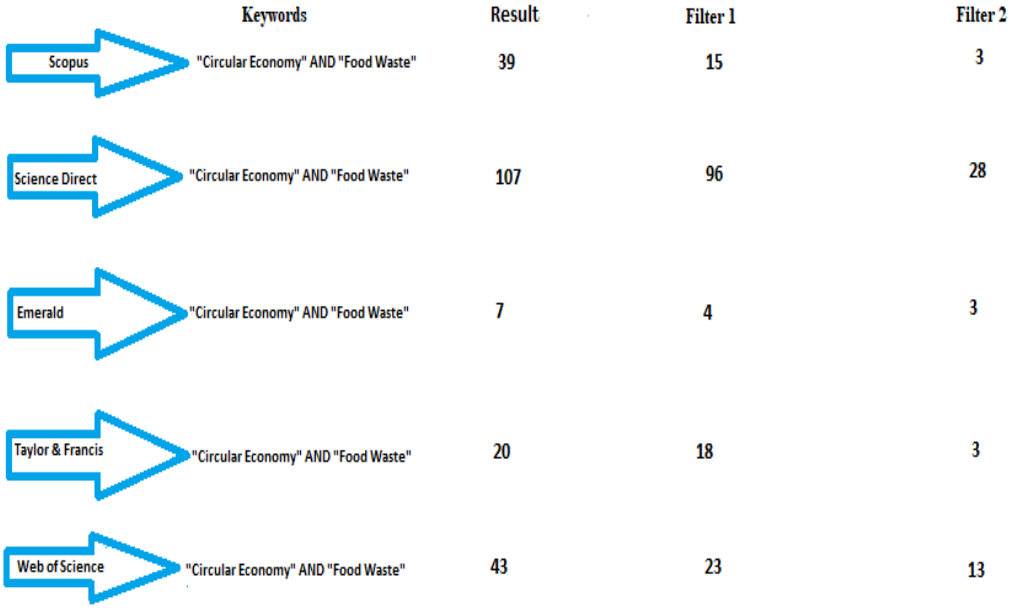
Steps	**Characteristics**
SLR Research Question	What are the main features of the international literature on food waste reduction in CE?
Definition of the set of inclusion and exclusion criteria	The criteria include the scientific base selected, publication period, types of articles, keywords and Boolean operators. Given the fact that the theme concerning the CE is multidisciplinary and that it may be found in journals of diverse areas, it was defined that research would take place in the scientific bases Science Direct, Scopus, Web of Science, Taylor & Francis and Emerald, which are multidisciplinary and comprise articles of journals with high impact factor and of diverse areas: Decision Analysis; Administration; Production Engineering; Civil Engineering; Mechanical Engineering; Software Engineering; Information Technology; Economics; Accounting Sciences; Mathematics; among others. Next, the publication period was established, which comprises articles published from 2010 to March

	31, 2020. As to keywords, the following were defined: "Circular Economy" AND "Food Waste".
Literature selection and access	Regarding the types of articles, it was defined that only full papers published in journals would be covered, which excluded articles published in annals of events, dissertations, theses, patents, books and book chapters, errata, among others. Regarding the Boolean operators used, only AND was chosen, excluding the NOT and OR operators. For the first selection, the papers should deal with the recovery and valorisation of food waste according to the reading of the title and abstract. A total of 216 articles were identified in the period from 2010 to March 31 2020. After reading the abstracts and titles, 166 were excluded for not properly addressing the topic of FW in the context of CE.
Quality assessment of the literature included in the review	It was found that only 50 fit the research theme, there was a repetition of 65 articles in the five (5) chosen bases and the other 101 were eliminated for being distant from the theme related to food waste in the context of CE. The remaining 50 articles were searched and compiled, highlighting the aspects related to the research question previously defined in step 1, involving: authors, publication period; sub-problem pertaining to food waste involving the context of CE.
Analysis, synthesis and dissemination of results	This phase covered the analysis of each article, necessary for the analysis and interpretation of the published works. Thus, charts, tables and figures were prepared with the main criteria used and respective authors. The fifty (50) papers were rigorously analysed.

Source: Authors.

In summary, Figure 1 illustrates the search conducted and the quantitative results found at each stage. The results section consisted of a search for articles from all years that contained the terms "Circular Economy" and "Food Waste" in the title or abstract or in the keywords of the articles and corresponded only to full articles published in journals and in English. Filtering 1 corresponds to articles that are repeated after analysis and selection. Filtering 2 corresponds to articles that have no adherence with the scope of the research.

Figure 1-Research and its results following the Systematic Literature Review Protocol



Source: Authors.

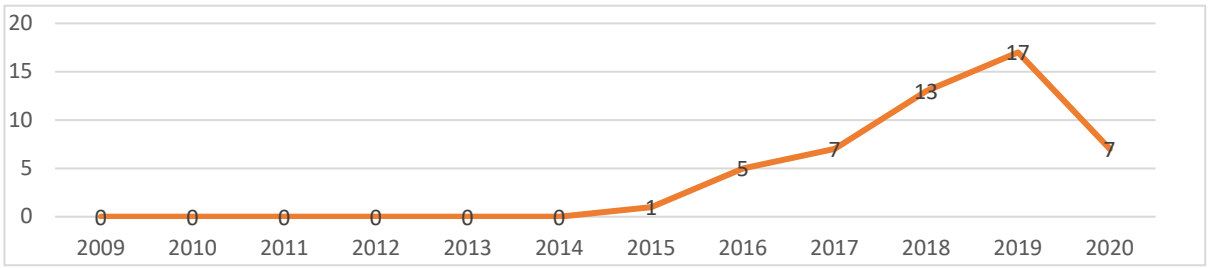
Then, Bardin's (1977) content analysis technique was used to analyze and interpret the articles found, because they can be adjusted to check common themes, according to the query of key elements in each study, transforming these individual findings into new interpretations (POLIT; BECK, 2006).

4 Results and discussions

4.1 International literature review

The results are presented considering the three established analytical dimensions: (i) demographics of publications, (ii) authors and institutions, and (iii) methods and techniques employed by researchers.

Figure 2- Number of publications per year



Source: Authors.

For the first dimension (Figure 2), the metadata of the scientific articles available in the databases consulted in this review were considered. Thus, when the annual evolution of scientific production on the topic is analyzed, a peak of 17 publications is found in 2019 and an increase in publications between 2014 and 2019. This period coincides with the discussions on food security in the Eurozone, held after the deep food crisis in the world, particularly in developing countries, between 2015 and 2019.

Figure 2 illustrates a recent and growing interest from researchers in food waste management from an EC perspective. It is apparently observed that in early 2020, there was a reduction in publications; this

due to the time cutoff considered until March 31, 2020.

When looking at the journals in which the studies were published, one verifies the interdisciplinary nature of the theme Food Waste versus Circular Economy, which are the main keywords of this study. The 50 articles found were published in a total of 26 journals. Only 6 of them published more than one study related to the theme under analysis according to Table 2, being 10 articles in Procedia Journal, 5 in Cleaner Production Journal, 5 in Sustainability Journal, 3 in Total Environmental Science Journal, 3 in Resource Conservation and Recycling Journal and 4 in Waste Management Journal. This interdisciplinary nature becomes clear when analyzing the category of the journals.

Table 2-Quantity of publications per journal category

Qt	CiteScore	Quotations in 2018	Scientific Journals
10	-	-	Procedia
5	7.32	43,324	Journal of Cleaner Production
5	3.01	13,880	Sustainability
4	6.15	40,039	Waste Management
3	6.82	4,096	Resources, Conservation & Recycling
3	5.92	40,039	Science of the Total Environment

Source: Authors.

The Journal Procedia maintains the supremacy of the journal that disseminates the most on the subject. This research highlights this journal as the primary vehicle for disseminating scientific research on food waste from an EC perspective. Other journals were also interested in the topic, as shown in Table 2. It is worth noting that these are journals from different parts of the world, mainly from Europe, and have different impact factors. The CiteScore (the metric developed by Scopus to measure the impact of scientific journals) and the number of citations obtained in 2018 (data collected from the Scopus website) were requested from these leading journals.

The 50 articles were written by 214 authors, with only 2 of them participating in more than one research on the topic under review (Table 3). This result indicates that there is no tradition of research by a particular university or research group. The remaining authors had only 1 published article.

Table 3- Number of authors per university

Quantities	Authors	Countries	Universities
2	Slorach	United Kingdom	University of Manchester
2	Corrado	Italy	Catholic University of the Sacred Heart

Source: Authors.

Table 4 shows the main countries with the highest number of publications. European countries are predominant, such as Italy with 15 publications and the UK with 11 publications.

Table 4- Number of publications by country

Countries	Quantities of publication
Italy	15
United Kingdom	11
Spain	6
Netherlands	4
Sweden	4
New Zealand	4
USA	3
China	2
Finland	2
Singapore	1
Germany	1
Taiwan	1
Ireland	1
Finland	2
New Zealand	4
Canada	1
Denmark	1
Romania	1
Croatia	1
Portugal	1
Austria	1
Latvia	1
Russia	1
Saudi Arabia	1

Source: Authors.

It can be seen that Italy and the UK are more interested in the subject than any other European country and there is little North American publication, making a total of 4. There is also no publication on the subject in the African continent, where there are more food insecurity problems, according to FAO (2018), and in Latin America, where there is a lot of food waste and loss (FAO *et al*., 2019).

In addition to these listed countries, 22 others were also represented in the studies, Spain, with six publications, the Netherlands, Sweden, and New Zealand with 4 publications each, and two publications in China and Finland. There is no Brazilian article written, which points to a scarcity of research on the topic in continents that experience much of the waste problem, as demonstrated by the data collected.

The second analytical dimension of this review aimed to characterize the keywords addressed. To identify the themes, the keywords of the studies were analyzed in wordart.net/create according to Figure 3.

Figure 3- Cloud of keywords of the systematic review articles

Source: Authors.

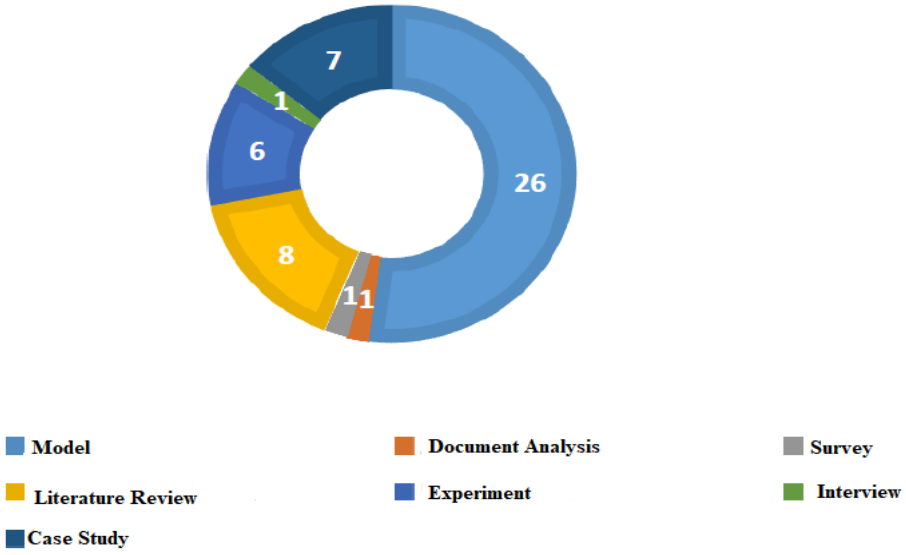
This word cloud illustrates the frequency with which terms are repeated as keywords, and it should be remembered that in the cloud concept, the more times the term is repeated, the greater the representation of the word. Thus, the analysis of the authors' is helpful in identifying the subjects of the research. The keyword "food" is the most repeated in the articles, appearing 63 times. It is followed by "Waste" with 58, "Circular" and "Economy" appearing repeatedly 20 times.

The terms "Food", "Waste", "Circular" and "Economy" are not surprisingly among the most frequently cited, as they were the words typed into the search engines. However, the words "Digestion" "Anaerobic", "Life" "Cycle", appearing respectively 9 times, are the primary means of food waste valorization suggested by the researchers, as they go beyond mere food waste recycling.

About the works that comprised the SLR, (18%) are purely qualitative, (46%) used the quantitative approach and (36%) the rest used the mixed approach. Notably, in the quantitative approach, there is the use of inferential statistical models, while in the qualitative research predominated the literature review and the case study as research procedures.

Regarding the techniques most used by the authors for data collection (Figure 4), it is worth noting that almost half of the studies were based on modeling (52%). It stands out, therefore, the concern of the authors to demonstrate the practical feasibility of circular models in the rescue of wasted food. The large number of literature reviews, case studies, and experiments demonstrates that researchers seek to find similarities, conceptual differences, theoretical knowledge, as well as models that enable replicability of results.

Figure 4- Characterisation of the research techniques



Source: Authors.

As for the studies' framework, it was observed that most of them are of theoretical-empirical nature (90%) and (10%) of the theoretical studies. The large number of theoretical-empirical studies stems mainly from the fact that the articles are based on projects funded by government agencies and international institutions of the European Union. In this context, these scientific articles serve as a basis for implementing circular models within organizations for the prevention and valorization of food waste along the food supply chain. These are projects that aim to develop integrated solutions to manage food waste recovery efficiently. Studies classified as theoretical refer mainly to the development of theoretical models, particularly in the area of chemistry.

The following analyses address the 50 studies identified in the third dimension, as already explained in the section that presented the method used in this work. Next, Table 5 shows the objectives of the categorized articles, according to the highest occurrence of a particular theme or keyword.

Table 5- Organisation of the articles according to the categorised objective

Categories: objectives keywords	Authors
Collaboration platform; industrial symbiosis.	Lowa *et al*. (2018); Albino *et al*. (2015); Bas-Bellver *et al*. (2020).
Bioeconomy strategy; monitoring and evaluation framework; decision support.	Sheppard *et al*. (2020); Pérez-Camacho *et al*. (2018); Velenturf & Jopson (2019); Erceg & Margeta (2019).
Autoclave method.	Chang *et al*. (2018).
Food waste management; sustainability; life cycle assessment (LCA); food waste prevention.	Slorach *et al*. (2020); Sala *et al*. (2017); Li *et al*. (2016); Van Bemmel & Parizeau (2020); Perez-Camacho *et al*. (2018); Corrado & Sala (2018); Garcia-Garcia *et al*. (2019); Martindale & Schiebel (2017); Notarnicola *et al*. (2017); Kubule *et al*. (2019); Bas-Bellver *et al*. (2020); Laso *et al*. (2016).
Food waste reduction policies.	Read *et al*. (2020); Irani *et al*. (2018); Liberti *et al*. (2018). Jurgilevich *et al*. (2016); Bas-Bellver *et al*. (2020); Philippidis *et al*. (2019).
Food waste biorefinery; anaerobic digestion (AD); biofuel; energy production.	Karthikeyan *et al*. (2017); Sadhukhan & Martinez-Hernandez (2017); Pecorini *et al*. (2018); Rehan *et al*. (2017); Pérez-Camacho *et al*. (2018); Rada *et al*. (2019).

Food assistance initiatives.	Hebinck *et al*. (2018); Tikka (2019); Liberti *et al*. (2018); Kubule *et al*. (2019); Jurgilevich *et al*. (2016).
Waste treatment; chemical treatment; recovery.	Li *et al*. (2016); Sadhukhan & Martinez-Hernandez (2017); Neves *et al*. (2019); Castrica *et al*. (2019); Jurgilevich *et al*. (2016); Laso *et al*. (2019).
Comparative studies between anaerobic digestion (AD), incineration, composting, landfill.	Slorach *et al*. (2018).
Waste hierarchy.	Hoehn *et al*. (2019).
Food safety and regulations.	Lucifero (2016); Velenturf & Jopson (2019); Mihai & Grozavu (2019); Erceg & Margeta (2019); Jurgilevich *et al*. (2016); Philippidis *et al*. (2019).
Sustainability of the food supply chain.	Xu &Wang (2016); Sala *et al*. (2018); Martindale & Schiebel (2017); Jurgilevich *et al*. (2016); Bas-Bellver *et al*. (2020); Laso *et al*. (2016).
Quantification of food residues.	Corrado & Sala (2018); Mason-D'Croz *et al*. (2019); Garcia-Garcia *et al*. (2019); Caldeira *et al*. (2019); Powell & Chertow (2018); Secondi *et al*. (2019); Kubule *et al*. (2019); Cobo *et al*. (2018); Jurgilevich *et al*. (2016).
Economic and environmental optimisation.	Sala *et al*. (2018); Rivera *et al*. (2018); Corrado *et al*. (2017); Udugama *et al*. (2020); Liberti *et al*. (2018); Mihai & Grozavu (2019); Erceg & Margeta (2019); Cobo *et al*. (2018); Bas-Bellver *et al*. (2020); Laso *et al*. (2016); Philippidis *et al*. (2019).
New innovative food packaging.	Rivera *et al*. (2018).
Materiality of food; behaviours of individuals.	Van Bemmel & Parizeau (2020).
Principles of circularity in the food system.	Van Zanten *et al*. (2019).
United Nations Sustainable Development Goals (SDGs); Food Supply Chain Management.	Stenton & Hanmer-Dwight (2019); Philippidis *et al*. (2019).
Innovative technological models; resource valorisation; simulation models.	Velenturf & Jopson (2019); Irani *et al*. (2018); Corrado *et al*. (2017); Garcia-Garcia *et al*. (2020); Caldeira *et al*. (2019); Powell & Chertow (2018); Udugama *et al*. (2020); Secondi *et al*. (2019); Liberti *et al*. (2018); Erceg & Margeta (2019). Reike *et al*. (2018); Philippidis *et al*. (2019); Rehan *et al*. (2017); Garre *et al*. (2020).

Source: Authors.

It was found that the categories "Food waste management; sustainability; life cycle assessment (LCA); food waste prevention," "Innovative technological models; resource valorization; simulation models," "Food waste quantification," "Economic and environmental optimization," "Food waste biorefinery; anaerobic digestion; biofuel; energy production," "Waste treatment; chemical treatment; valorization," "Food waste reduction policies," and "Food safety and regulations" are the emerging themes with the highest incidence in the research. Therefore, the categories with lower prominence indicate research opportunities for future studies and themes that have gained less attention in recent years for the area researched. To date, there are few studies in which the circularity principles pointed out by SLR are explored.

4.2 Research agenda

Table 6 presents the propositions for future research raised by the authors of the articles analyzed in the SLR, where there are relevant suggested directions. They have been grouped into categories in order to show which type of future study suggestion topic is the most relevant.

Table 6- Organization of the articles according to suggestions for future work

Categories of themes proposed for future work	Authors

There are non-technical barriers to be overcome; financial barriers.	Lowa *et al*. (2018); Sheppard *et al*. (2020); Velenturf & Jopson (2019); Philippidis *et al*. (2019).
Fertilisers; biogas; integrated refinery; power generation; national grid; self-consumption.	Chang *et al*. (2018); Karthikeyan *et al*. (2017); Hoehn *et al*. (2019); Pecorini *et al*. (2018); Philippidis *et al*. (2019).
Economic and environmental optimisation; mathematical modelling; screening; quantification; mapping; predictive model projection; technology selection for Food Supply Chain Management; innovation; life cycle assessment (LCA).	Garre *et al*. (2020); Karthikeyan *et al*. (2017); Hoehn *et al*. (2019); Xu & Wang (2016); Corrado & Sala (2018); Mason-D'Croz *et al* (2019); Sala *et al*. (2017); Rivera *et al*. (2019); Van Bemmel & Parizeau (2020); Corrado *et al*. (2017); Caldeira *et al*. (2019); De Laurentiis *et al*. (2018); Powell & Chertow (2018); Kubule *et al*. (2019); Maso *et al*. (2016); Rehan *et al*. (2017).
Separate collection of food waste for treatment via anaerobic digestion (AD) should be encouraged.	Slorach *et al*. (2020); Slorach *et al*. (2018); Pecorini *et al*. (2018); Pérez-Camacho *et al*. (2018); Philippidis *et al*. (2019).
Prevention is still the best way to achieve significant environmental and economic benefits; decision making.	Slorach *et al*. (2020); Liberti *et al*. (2018); Martindale & Schiebel (2017); Rehan *et al*. (2017).
Minimisation; environmental impact; access to food; waste reduction policies in Food Supply Chain Management.	Read *et al*. (2020); Mason-D'Croz *et al*. (2019); Mihai &Grozavu (2019); Cobo *et al*. (2019); Jurgilevich *et al*. (2016); Bas-Bellver *et al*. (2020); Li *et al*. (2016).
Specific environmental legislation; targets; waste valorisation; public policies for CE.	Karthikeyan *et al*. (2017); Mason-D'Croz *et al*. (2019); Pérez-Camacho *et al*. (2018); Jurgilevich *et al*. (2016); Rehan *et al*. (2017). Li *et al*. (2016).
Possible avenues of investigation would be the role of narratives such as "the right to food" from "inside" the food bank and the new relations of social movements to forms of food assistance practices.	Hebinck *et al*. (2018).
The changing social responsibility of the state.	Tikka (2019); Mason-D'Croz *et al*. (2019).
Application of industrial symbiosis (IS) in practices according to the realities of each city/region.	Albino *et al*. (2015); Jurgilevich *et al*. (2016).
Need for transformative partnerships aligned to the United Nations Sustainable Development Goals (SDGs).	Stenton & Hanmer-Dwight (2019).
Composting	Erceg & Margeta (2019); Philippidis *et al*. (2019).
Valorisation of food/organic waste.	Irani *et al*. (2018); Sadhukhan & Martinez-Hernandez (2017); Garcia-Garcia *et al*. (2019); Bas-Bellver *et al*. (2020); Philippidis *et al*. (2019).
Commercialisation of renewable energy production technologies.	Udugama *et al*. (2020).
Research regarding waste at the consumer level; unique data; specific products; need for knowledge about other supply chains.	Secondi *et al*. (2019).
Operation in synergy.	Liberti *et al*. (2018); Jurgilevich *et al*. (2016).
Traditional routes (home composting, animal feed, household waste recovery) should be improved and supported by the rural community.	Mihai & Grozavu (2019).
Socio-economic and institutional measures; redefinition of quality of life.	Van Zanten *et al*. (2019).
Aqueous biphasic systems, composed of bistriflimid ionic liquids and carbohydrates are a promising platform to simultaneously separate carbohydrates and antioxidants from food residue.	Neves *et al*. (2020).
Conceptualising circular models by focusing on options for retaining history and resource value.	Reike *et al*. (2018).

Finding a balance between quantities and qualities, as well as exploring implementation possibilities in LCA.	Notarnicola *et al*. (2017).
Storage and processing.	Castrica *et al*. (2019); Bas-Bellver *et al*. (2020).
Anaerobic digestion (AD) and hydrothermal carbonisation reactor (HTC) methods in middle income countries.	Rada *et al*. (2019).

Source: Authores.

In total, there were 23 categories of articles that were the topics suggested by the authors for future research. It can be seen that the most prominent categories of relevant papers were "Economic and environmental optimization; mathematical modeling; tracking; quantification; mapping; predictive model projection; selection of technologies for Food Supply Chain Management; innovation; life cycle assessment (LCA)", "Separate collection of food waste for treatment via anaerobic digestion (AD) should be encouraged", "Prevention; decision making", "Minimizing environmental impact and improving access to food; reduction policies; Food Supply Chain Management", "Specific legislation; targets; waste; public policies" and "Food waste valorization".

It can be inferred that such categories that showed more prominence should be taken into consideration in future work for effective food waste management from the EC perspective. In addition, the categories in Table 6 show the relevance of food waste topics within the EC framework presented by authors in the field for the development of future work. Given the description and discussion conducted so far, one notes the great diversity of articles presented in different international journals and the importance that this issue represents for the food security scenario in the world, particularly in developing countries.

This study investigated the current state of research regarding food waste management using different CE models to mitigate the latter's advancement in our society. The circular methods pointed out by other researchers are efficient but expensive. In this regard, researchers suggest for future research synergy between Food Supply Chain Management actors and actors from developed and developing countries, a conceptualization of circular models using the focus on historical retention options and value of resources, a balance between quantities and qualities, as well as exploring the possibilities of LCA implementation and surplus food sharing policies. Meanwhile, other researchers suggest implementing waste recovery and valorization tools in low-income countries, where the highest avoidable and unavoidable waste is recorded (FAO, 2018).

The studies showed that several recovery techniques have been carried out in different developed countries, but are still in an embryonic state due to financial limits, weak environmental legislation in force and the lack of strict public policies on waste. It is observed that the researchers' suggestions were fruitful for the academic community, because through this SLR it is realized that there is still a lack of studies on prevention, recovery and valorization of food waste in developing countries, particularly in Brazil, in the field of CE. In addition, it is observed that food waste management in the Brazilian scenario seems to be forgotten and, so far, no publication by Brazilian researchers pointing out the reuse and recovery of food waste in international literatures in the CE sphere was found, considering the inclusion and exclusion criteria defined for this SLR.

It is expected that with further academic research the principles of circularity will become part of the priorities of Brazilian public policies, since a decade ago there is the National Solid Waste Policy (PNRS) in Brazil. Thus, we can see a mitigation of waste, transforming it into new raw materials to minimize the

environmental impact and stimulate the growth of the world economy by reducing the generation of food waste and creating new jobs not only in developed also in developing countries.

Of the 50 reviewed SLR articles, the research gaps identified indicate that most studies focused on developed countries. In addition, no studies on food waste under CE were identified in African countries which are the most vulnerable food insecure countries (FAO, 2018). Furthermore, it is observed that most researchers are more concerned with quickly addressing food waste issues in developed countries and not in developing countries that suffer more from food waste at the beginning of production (processing, distribution and consumption) (GUSTAVSSON *et al*., 2011). It is also notable that there are studies reporting cases, mainly from developed countries.

Li *et al*. (2016) highlight that most developing countries still do not fully practice food waste recycling. As a result, most food waste mixes with solid waste and is then landfilled, contributing to increased air emissions. In addition, environmental legislation remains unenforceable and most of the aid for recycling activities and projects comes from international organizations. At the same time, developing countries set a low budget for segregation of waste activities and treatment facilities. Therefore, inadequate food waste management problems in developing countries stem from incompatible administrative measures and misallocation of budget resources in increasing recycling activities.

In this context, food waste management is seriously absent in the legislations and regulations of developing countries, where official CE policies, regulations and plans for food waste are lacking (KINOBE *et al*., 2015).

It can be noted that there is still a long way to go in the context of food waste reduction, due to the constant production of large agro-food industries and the marketing effects that often encourage the consumption of new products in the market. On the other hand, we are witnessing a rapid depletion of the planet's natural resources and increased food insecurity, particularly in developing countries.

Researchers should consider conducting field research integrating all actors in the supply chain, through interviews, workshops, surveys, focus groups, and case studies, ethnographic and phenomenological studies, in order to understand better the main causes of food waste in value and production chains and address them, rather than focusing only on positivist models, as observed in SLR.

5 Conclusions

CE is one of the main guidelines for countries, cities and companies to move towards sustainable development in the coming years (GRAVAGNUOLO *et al*., 2019). In this context, the search for legitimacy is necessary, respecting the environmental standards and regulations in force in each country to mitigate the problems linked to food waste, transforming it into inputs, raw materials, and energy along the food supply chains.

This paper analyzed the state of the art of CE in food waste in the international literature. In this sense, scientific articles published in English in five databases were searched: Science Direct, Scopus, Web of Science, Scopus, Taylor & Francis and Emerald. The steps were described, the filters and the inclusion and exclusion criteria were detailed, and 50 articles on the subject were analyzed (Table 1).

There is a growing interest among academics and professionals in the area. It can be seen that the most productive authors/institutions are concentrated in Europe (Table 4), possibly because there are guidelines for the European community and legislation dealing with circular legislation in these countries economy and *food waste*. According to the authors, most of the studies focus on mathematical

modelling, which is the most promising in reducing food waste. Other authors have also focused on innovative technologies, such as the use of the Internet of Things in waste prevention.

The authors addressed food waste reuse techniques, such as recycling, quantification, anaerobic digestion, life cycle assessment, composting, industrial symbiosis (Figure 3). Furthermore, it is highlighted that the most used methods by the researchers were the quantitative approach (46%), while few authors used the qualitative approach (18%) and the others, the mixed approach (36%).

Furthermore, a research agenda was presented that provides guidance for further studies that can be oriented towards paradigm shifts, engagement of stakeholders, CSA actors, policy makers, decision makers, consumers and society at large to promote circularity through legislation and regulations; towards comprehensive monitoring and analysis through quantitative environmental performance indicators and towards the applicability of conceptual models and projects (Table 6).

From this literature review, it can be seen that there are still few studies on the CE of food waste in supply chains, especially concerning developing countries and with a focus on CE, as this is a relatively recent concept in the literature, with little theoretical consolidation. Food waste is part of the biological cycle of CE and can be reclaimed and reinserted into it, or into other supply chains, to mitigate the problem of waste and increased air emissions. Demonstrating state of the art on the subject and gaps to be developed in future studies can guide researchers in relation to issues not yet explored in the context of CE and indicate to managers possible paths for the adoption of CE focused on food waste.

In addition, the recent literature review developed by Dora *et al*. (2021), showed that there are few studies regarding CE food waste in developed countries than in underdeveloped countries. These findings corroborate with the results found in our SLR. This should draw the attention of practitioners in the field to see which path of CE can suit the context of developing countries in preventing and reducing food losses and waste.

As practical implications, this study can also help managers develop public policies and guidelines on how to add value to organizations in the economic, social, and environmental spheres from food waste reduction to guide food supply chain actors to benefit from a healthy and regenerative circular food system.

The study's limitations refer mainly to the choices made regarding the search protocol chosen, the filters applied, the timeframe, and the scientific bases selected. Furthermore, the work did not exhaust the national and international literature (periodicals, bases, annals of events, theses, dissertations, books). Besides the research agendas already suggested, future studies may choose other bases and protocols to compare the results. It is believed that EC deserves to gain the robustness essential to continue growing, not only in academia, but also in public and private organizations. Future studies may use other protocols such as Methodi Ordinatio, Procknow C, Meta-Analysis among others in order to select and filter data sources. They may also define different inclusion and exclusion criteria, which complement the publication period, and cover other materials not considered in this SLR. In addition, studies that propose standardized quantitative methods for waste quantification and that study waste in various supply chain actors such as: retailers, wholesalers, restaurants, short chains such as fairs, and the consumer may bring to light the gaps presented in this research.

Finally, this study contributed to a theoretical overview of the evolution of international publications on food waste, pointing out different methods used by researchers and different circular models developed in developed countries with their social, economic and environmental

benefits for the academic community and society in general.

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