FOOD LOSS AND WASTE WORLDWIDE: AN ANALYSIS OF THEORIES, ACTIONS AND GOVERNANCE

Perda e desperdício de alimentos no mundo: uma análise de teorias, ações e governança

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Abstract: This paper aimed to answer the following questions: (i) What theoretical approaches have been proposed to explain patterns of FLW around the world? (ii) How can a better understanding of governance relationships in agri-food systems contribute to reducing FLW? (iii) How can food, input and material suppliers, and processing sectors and buyers work together to develop more sustainable agri-food systems? To this end, the aim of the paper was to analyze the theories related to the topic, the governance relationships in agri-food systems and actions carried out by actors in the food, input and/or material supply network. The methodological procedure involved a systematic quantitative literature review to map the available literature on FLW. The quantitative bibliometric tool Bibliometrix of the R software was used. The results show that the main approaches included life cycle analysis for assessing environmental impacts, assessment of the supply chain and stakeholder actions, estimates of the weight of food losses, discussions on the circular economy and analysis of socio-technical transitions. The articles that addressed governance showed the need for stakeholders to contribute to the development of packaging solutions with a better environmental profile. The originality of the study lies in its approach to the topic and the adoption of little-explored perspectives, such as theories that discuss FLW and governance practices in supply chains. The study incorporates several disciplines, adopting a multidisciplinary approach. Thus, it was possible to identify significant gaps in the existing literature and suggestions for future research.

Keywords: corporate actions, governance, loss reduction, foods.

Resumo: Este artigo teve como objetivo responder às seguintes perguntas: (i) Quais abordagens teóricas foram propostas para explicar os padrões de PDA em todo o mundo? (ii) Como uma melhor compreensão das relações de governança em sistemas agroalimentares pode contribuir para a redução de PDA? (iii) Como os fornecedores de alimentos, insumos e materiais, e os setores de processamento e os compradores podem trabalhar juntos para desenvolver sistemas agroalimentares mais sustentáveis? Para isso, o objetivo do artigo foi analisar as teorias relacionadas ao tema, as relações de governança em sistemas agroalimentares e ações realizadas por atores da rede de abastecimento de alimentos, insumos e/ou materiais. O procedimento metodológico envolveu uma revisão quantitativa sistemática da literatura para mapear a literatura disponível sobre PDA. Foi utilizada a ferramenta bibliométrica quantitativa Bibliometrix do software R. Os resultados evidenciam que as principais abordagens incluíram a análise do ciclo de vida para a avaliação dos impactos ambientais, avaliação da cadeia de abastecimento e ações das partes interessadas, estimativas de peso das perdas de alimentos, discussões sobre economia circular e análise de transições sociotécnicas. Os artigos que abordaram governança mostraram a necessidade dos stakeholders contribuírem para o desenvolvimento de soluções de embalagens com melhor perfil ambiental. A originalidade do estudo reside na abordagem do tema e na adoção de perspectivas pouco exploradas, como teorias que discutem PDA e práticas de governança em cadeias de suprimentos. O estudo incorpora diversas disciplinas, adotando uma abordagem multidisciplinar. Assim, foi possível identificar lacunas significativas na literatura existente e sugestões para pesquisas futuras.

Palavras-chave: ações corporativas, governança, redução de perdas, alimentos.

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1 INTRODUCTION

In the last decade, FLW has been the focus of intense debate by the United Nations Food and Agriculture Organization (FAO). Food losses refer to the reduction in edible food mass along the supply chain, specifically concerning food for human consumption. Such losses may occur in the production, post-harvest, or processing phases (Parfitt *et al*., 2010; FAO 2012; 2019). On the other hand, food waste refers to losses that occur at the end of the food chain, related to the behaviour of retailers and consumers (Parfitt *et al*., 2010; FAO, 2012; 2019).

Food losses represent between a quarter and a third of all food produced annually for human consumption (1.3 billion tonnes), according to 2023 data (Benítez, 2023). In Latin America and the Caribbean, food losses are estimated at 10% to 15%, which is above the rate of more developed regions, such as Australia, New Zealand, and countries in East, Southeast, and West Asia (FAO, 2019; Benítez, 2023). In both developing and developed nations, food losses can arise from premature harvesting, whereby farmers harvest crops too early, likely due to food shortages or the pressing need for financial resources in the latter part of the harvest season. Crops harvested before maturity have lower nutritional and economic value, and may be wasted if deemed unsuitable for consumption. A possible prevention action is for small-scale farmers to organize themselves into groups or cooperatives and produce a variety of cash crops and livestock, decreasing the dependence on a single resource. Farmers could also apply for loans from agricultural financial institutions or prepayment from buyers. Another strategy is marketing diversification (FAO, 2012).

In developing countries, poor storage facilities and lack of infrastructure are important causes of food losses, even in the post-harvest phase. Fresh produce, such as fruits, vegetables, meat, and fish can spoil in hot climates due to lack of infrastructure for transportation, storage, cooling, and marketing (Rolle, 2006; FAO, 2012). Such observations on the causes of upstream FLW in developing countries are corroborated by the results of Dora *et al*. (2021). Based on a comprehensive systematic review (1998 to 2018) of FLW and the circular economy, the authors developed a conceptual model for FLW prevention.

These findings point to the need for restructuring supply chains to mitigate FLW in developing countries, with actions aimed at production, post-harvest, and processing. Furthermore, the observations shed light on challenges related to the coordination and organization of food systems, particularly sustainable ones. Food systems comprise a set of actors and their relationships influencing the production, aggregation, processing, distribution, consumption, and disposal of products derived from agriculture, forestry, or fisheries, as well as the broad economic, social, and natural environments in which they are included (FAO, 2018).

In view of this, this article aimed to answer the following questions: (i) What theories have been proposed to explain FLW patterns worldwide? (ii) How can a better understanding of governance relationships in agrifood systems contribute to reducing FLW? (iii) How can food, input, and material suppliers, processing sectors, and buyers work together to develop more sustainable agrifood systems? In the next sections, we outline the methodological procedures, present a systematic review of the literature on FLW, discuss the major contributions of selected studies, and provide concluding remarks.

2 METHODOLOGICAL PROCEDURES

A systematic literature review, employing explicit and replicable methods, is the preferred approach when addressing a substantial research theme. This holds true even in cases where the theme is complex or there is limited existing research (Fink, 2019). Systematic reviews seek to minimize biases that may arise from specific interests or the disciplinary focus of researchers (Tranfield *et al*., 2003). According to Staples and Niazi (2007), a systematic literature review is undertaken to investigate and analyse published articles with the aim of addressing specific research questions. This method enables researchers to understand the structure of existing studies and identify gaps in the literature, shedding light on topics

that offer potential for future research (Kitchenham, 2004).

The study adopted a quantitative approach to map the available literature on FLW. The quantitative tool Bibliometrix of R software was used to construct a logical bibliometric workflow. R is extensively used in research because it is an object-oriented and functional programming language, making it easy to automate analyses and create functions (Aria and Cuccurullo, 2017). Data were collected through a systematic literature review, chosen for its relevance in knowledge construction. This method offers advantages in terms of enhancing rigour, validating research, and minimizing bias concerning the proposed objectives (Tranfield *et al*., 2003). Here, we followed the three macro stages proposed by Tranfield *et al*. (2003).

Articles were searched in Web of Science and Scopus databases. These two databases were chosen for their reliable and comprehensive coverage and up-to-date content compared to other databases. These databases have the additional advantage of being compatible with Bibliometrix. Search terms were entered and the 'all fields' option was selected. This procedure was taken to ensure that we would locate, select, and analyse the largest number of relevant studies discussing the investigated theme. The document type was set to 'article', without date limitation. Articles written in the following three languages were included: English, French, and Portuguese. Given the breadth of publications, it was also necessary to limit results to the fields of administration, agribusiness, and agriculture, as well as multidisciplinary studies related to these fields.

Defining the appropriate research questions is a crucial step that shapes the trajectory of an investigation. Well-crafted research questions help address challenges related to data collection and analysis (Bryman, 2007). Research questions, keywords, and search strings are presented in Table 1.

Table 1 – Research questions, keywords, and search strings used in the systematic literature review on food loss and waste

Research question	Keywords	Search string
What theories have been proposed to explain FLW patterns worldwide?	Food loss, Food waste, Agrifood system, Theor*	"food loss" OR "food waste" AND "agri-food system" AND "theor*"
How can a better understanding of governance relationships in agrifood systems contribute to reducing FLW?	Food loss, Food waste, Agrifood system, Governance	"food loss" OR "food waste" AND "agri-food system" AND "governance"
How can food, input, and material suppliers, processing sectors, and buyers work together to develop more sustainable agri-food systems?	Agrifood system, Sustainable, Actions, Processing, Industry, Suppliers, Buyers	"agrifood system" AND "sustainable" AND "actions" AND "processing" OR "industry" AND "suppliers" AND "buyers"

Source: prepared by the authors (2023).

Table 2 presents the study protocol, detailing all the steps in the systematic literature review.

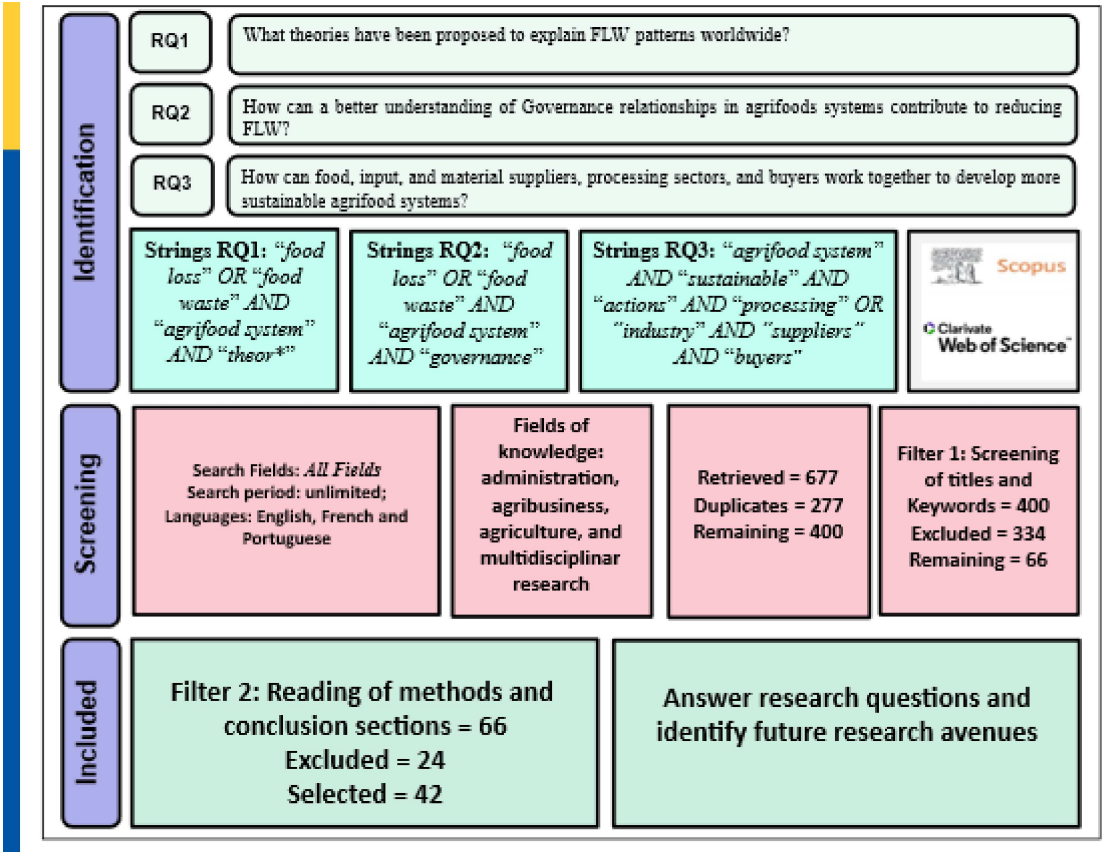
Table 2 – Systematic review protocol

Stage	Steps	Description
Planning	Formulation of research questions	Review questions are defined according to the purpose of the study
	Development of the review protocol for identification of relevant articles	Research development (Figure 1)
		Database search: Scopus and Web of Science
		Search fields: All Fields
		Search period: unlimited
		Languages: English, French, and Portuguese
Conduction of the review	Article selection and evaluation	Filter 1: screening of titles, abstracts, and keywords
		Filter 2: full text screening
	Analysis and synthesis	Selected articles are read in full
Communication and dissemination	Presentation of reports	Research questions are answered
		Main points and existing gaps are summarized

Source: prepared by the authors (2023).

Figure 1 illustrates the filtering process, as highlighted in the research protocol (Table II), according to the Transparent Reporting of Systematic Reviews and Meta-Analyses flowchart model (PRISMA).

Figure 1 – Filter strategy. Source: prepared by the authors (2023)



3 RESULTS AND DISCUSSION

The searches performed in the Web of Science and Scopus databases retrieved a total of 677 articles. These articles were exported to Excel using the BibTeX extension and then exported to Bibliometrix using the Biblioshiny application of R software. Thus, it was possible to identify 277 duplicate articles, which were excluded. This tool was also used to create a new Excel spreadsheet containing information on each article.

The resulting dataset contained 334 articles, which were subjected to an initial screening step consisting of reading titles, keywords, and abstracts. In this screening phase, all articles that did not focus primarily on FLW or sustainable supply chain management were excluded. A total of 66 articles were selected for the last screening step. After full-text screening, a total of 42 articles were selected to answer the research questions. This set of 42 articles was compiled and used to develop a synthesis of knowledge, as presented in Table III.

3.1 Bibliometric analysis

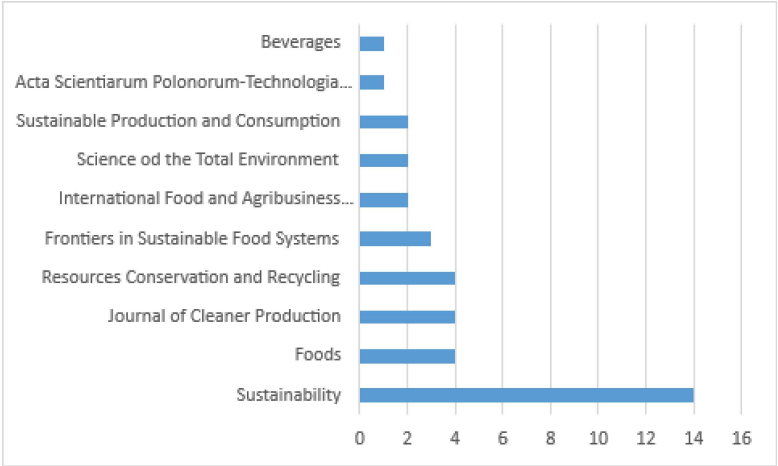
A total of 244 authors/researchers contributed to the production of the set of 66 articles. A three-field plot showing author keywords and countries from all articles, as well as their interrelationships with countries, was generated. The results evidenced that the United States, United Kingdom, Italy, Germany, and Australia were the main countries where researchers work with themes related to FLW. The United States, for example, excels in research on food waste, food loss, FLW, sustainability, supply chain, food safety, primary production, diet, and food systems. Brazil, on the other hand, holds a relevant position in terms of research on FLW, particularly with regard to supply chain research.

The main author keywords in the selected articles were sustainability, supply chain, and circular economy. It was also found that co-authors from several countries, such as the United States, United Kingdom, Italy, Germany, Australia, Denmark, Costa Rica, Portugal, Bangladesh, Hungary, Norway, Iran, and Switzerland, relate FLW mainly to management, impacts, and structure. Figure 2 shows the most frequent terms found in the sample of articles selected in this study.

Figure 2 – Word cloud. Source: prepared by the authors using Bibliometrix (2023)

Frequency analysis revealed that the most frequent keyword was management (n = 13), followed by impacts (n = 12), structure (n = 7), supply chain (n = 6), and sustainability (n = 5). The least frequent keywords were science, post-harvest, and storage. These findings suggest that further research on these little-explored topics might help mitigate FLW. The word 'temperature' was also among the least frequent, pointing out the need for more studies, reflections, and understanding of the impacts of temperature, climate change, and global warming on FLW. Figure 3 depicts the most relevant journals in FLW research identified in the bibliometric analysis.

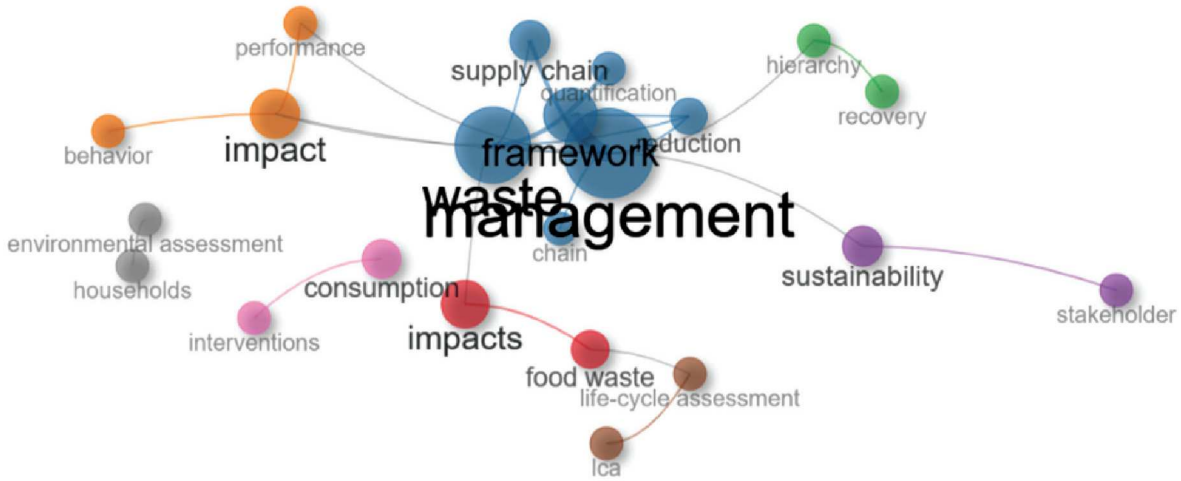
Figure 3 – Most relevant journals in food loss and waste research. Source: prepared by the authors using Bibliometrix (2023)



The most relevant source of articles was *Sustainability*. In general, it was observed that the most important journals addressing FLW in this bibliometric analysis incorporated an environmental dimension, including aspects of sustainability, cleaner production, resource conservation and recycling, sustainable food systems, and sustainable production and consumption. This shows the importance of avoiding FLW to contribute to the achievement of the SDGs and planetary health.

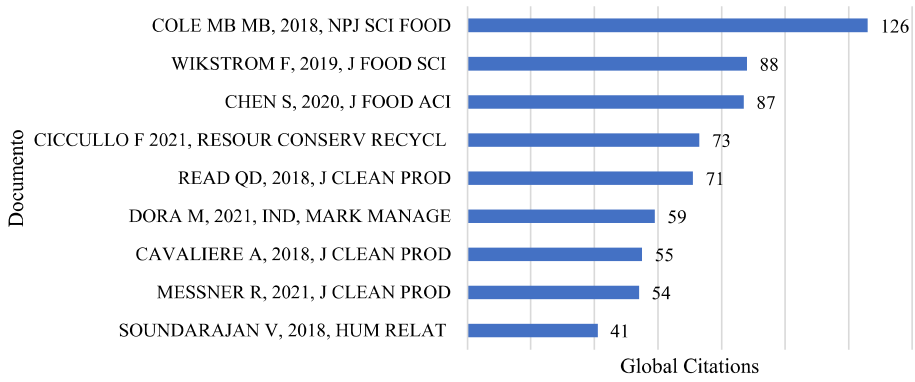
The top-ranking countries in terms of scientific production were the United States, Ukraine, Italy, Germany, and Australia. Figure 4 presents the keyword co-occurrence networks of the analysed articles. This conceptual structure depicts links between co-occurring terms and is commonly used to identify the most important and recent themes in a field of research (Aria and Cuccurullo, 2017).

Figure 4 – Co-occurrence network of keywords. Source: prepared by the authors using Bibliometrix (2023)



The co-occurrence network is formed by several clusters. The blue cluster contains central keywords to the studied sample. The results reveal the relevance of supply chain management to reduce and quantify FLW in various existing structures, as well as the researchers' concern with sustainability management, given the impacts of FLW. Figure 5 shows the most cited articles addressing this theme.

Figure 5 – Most-cited articles on food loss and waste. Source: prepared by the authors using Bibliometrix (2023)



The most-cited article is entitled 'The science of food security'. The second is entitled 'Packaging strategies that save food: a research agenda for 2030'. The third is 'The role of smart packaging system in food supply chain'. The fourth is 'Implementing the circular economy paradigm in the agrifood supply chain: the role of food waste prevention technologies' and the fifth is 'Assessing the environmental impacts of halving food loss and waste along the food supply chain'.

3.2 Approaches, governance practices, and actions taken to establish sustainable agrifood systems

This subsection addresses the research questions (i) What theories have been proposed to explain FLW patterns worldwide? (ii) How can a better understanding of governance relationships in agrifood systems contribute to reducing FLW? (iii) How can food, input, and material suppliers, processing sectors, and buyers work together to develop more sustainable agrifood systems?

Table 3a – Synthesis of knowledge on food loss and waste (FLW)

References	Theme, geographical scope
Röös *et al.* (2023)	Food system, Sweden
Pereira et al. (2022)	Soybean production chain, Paraná State, Brazil
Surucu-Balci and Tuna (2022)	Fruit and vegetable chain, Turkey
Matsumoto (2022)	Recall of imported food products, Japan
Dong *et al*. (2022)	Food supply chain, United States
Magalhães et al. (2022)	Fruit and vegetable supply chain, Portugal
Amani and Sarkodie (2022)	Samples of healthy and spoiled red meat collected in a supermarket, Turkey
Bux and Amicarelli (2022)	Material flow in the poultry sector, Italy
Herzberg et al. (2022)	Fruit and vegetable supply chain, Germany
Lu *et al*. (2022)	Losses of vegetables, fruits, and staple crops, China
Dergan *et al*. (2022)	Legume agrifood chain, Slovenia
Küchler and Herzig (2021)	Food supply chain, Germany
Roesler at al. (2021)	Agrifood supply chain, Germany
Alshabanat *et al*. (2021)	Wheat, rice, dates, vegetables, fruits, meat, chicken, and fish chains, Saudi Arabia
Islam et al. (2021)	Cold food supply chain (fish), (several countries involved)
Ortiz-Gonzalo *et al*. (2021)	Vegetable supply chain, Thailand
Gorter *et al*. (2021)	Chicken and fruit chain, The United Kingdom
Cammarelle et al. (2021)	Food and beverage industry, Italy
Toth *et al*. (2021)	Milk factory, Hungary
Ciccullo *et al*. (2021)	Food waste in the fruit and vegetable segment, Italy
Ranaei *et al*. (2021)	Meat food chain, Iran

Source: prepared by the authors (2023).

Table 3b – Synthesis of knowledge on food loss and waste (FLW) (Continuation)

References	Theme, geographical scope
Messner et al. (2021)	Overproduction and surplus in the horticulture supply chain, Australia
Bolanos-Palmieri *et al*. (2021)	Food waste, Costa Rica
Campos-Rodriguez *et al*. (2021)	Fruit processing for pulp and beverage production, Costa Rica
Chauhan (2020)	Food industry, India
Kleineidam (2020)	Generic food chain
Read *et al*. (2020)	Estimated loss rates of 11 food groups in five stages, United States
Chen *et al*. (2020)	Smart packaging
Jafari *et al*. (2020)	Food waste, European Union
Baker *et al*. (2019)	Different agricultural crops, California, USA
Bilska et al. (2019)	Losses of dairy products, Poland
Wohner *et al*. (2019)	Packaging of dairy products, Austria
Wikstrom *et al*. (2019)	Packaging strategies
Secondi *et al*. (2019)	Reuse of food waste in a tomato sauce company, Italy
Verma *et al*. (2019)	Tomato chain in Nigeria
Pappa et al. (2019)	Dairy industry, Greece
Porter *et al*. (2018)	Fruits and vegetables, The United Kingdom
Chen and Chen (2018)	Investigation of food waste prevention and diversion, United States
Bacenetti *et al*. (2018)	Wholemeal bread chain in Italy
Woodhouse *et al*. (2018)	Sustainability checklist based on LCA theory
Sjauw-Koen-Fa et al. (2016)	Relationship between small producers and large agribusiness companies
Mouron et al. (2016)	French fries supply chain, Switzerland

Source: prepared by the authors (2023).

The articles used different approaches to the topic, the main ones being environmental impacts of the food life cycle, supply chain and stakeholder actions, weight estimates of food losses, circular economy, and sociotechnical transitions. For instance, Dong et al. (2022) estimated mass flow and FLW along the food supply chains of 10 commodity groups and 9 management systems in the United States. Their aim was to devise efficient strategies to reduce, recycle, and recover FLW. Lu et al. (2022) quantified losses in staple crops, vegetables, and fruits using primary data from China. Alshabanat et al. (2021) calculated losses in Saudi Arabia associated with wheat, rice, dates, poultry, vegetables, fruits, fish, and meat using the FAO model proposed by Gustavsson et al. (2013) and FAO (2014).

Using the life cycle approach, Mouron et al. (2016) compared the environmental impacts of losses of fresh and fried potatoes in Switzerland. Wohner et al. (2019) analyzed the emptiability of dairy products in Austria, focusing on the environmental footprint of the chain. Falcone, Giovenzana and Guidetti (2018) evaluated the life cycle of whole-grain toast to determine whether extending the shelf life is an effective mitigation solution from an environmental point of view.

Chauhan (2020) surveyed the supply chains of different food processing organizations in India to assess the role of technology platforms aimed at reducing food waste. Gorter et al. (2021) discussed the economic model of food waste for various agents of the supply chain in the United Kingdom, in the context of chicken and fruit products. The authors showed that the impacts of waste reduction vary according to the commodity, depending on the elasticity of supply and demand, degree of openness to international trade, and initial FLW rates at each stage of the value chain.

Read et al. (2020) used an environmentally extended input–output model articulated with data on FLW rates to calculate the scale of the total environmental impacts of the United States food system associated with FLW. Bilska and Kolozyn-Krajewska (2019) developed a risk management model for dairy product losses using the example of cheese ripening (with data from Polish organizations). The authors found that lowering the redistribution or sale prices of products was effective in reducing product disposal.

From the point of view of governance associated with FLW, Bolanos-Palmieri et al. (2021) contributed to the topic by underscoring the need for multi-lateral and multi-dimensional approaches to addressing the issue. The authors portrayed the Costa Rica FLW Reduction Network, created in 2014, as a collaborative platform between different sectors and disciplines to promote change through communication, awareness, alliances, research, and innovation. The main findings showed that collaborative actions between institutions and sectors are vital to reducing FLW; however, FLW innovation is still in its early stages, and financial and political barriers are present. These conclusions are in line with the findings of Kleineidam (2020) and Pappa and Massouras (2019).

In the context of organizational and inter-organizational actions, Wikstrom et al. (2019) carefully analyzed how packaging systems can prevent FLW. The suggested strategies were the following: identify and obtain specific data from packaging functions that influence food waste; understand the total environmental burden of the product/package, considering the trade-off between product protection/preservation and environmental footprint; improve packaging design processes to encompass food waste reduction; and analyse stakeholder incentives to reduce FLW.

Cammarelle and Viscecchia (2021) investigated the willingness of food and beverage manufacturers to invest in packaging innovations, such as active, smart, and biodegradable packaging. To achieve their objective, the authors conducted a multiple case study with a sample of Italian micro-, small-, and medium-sized enterprises located in the Apulia region. The results showed that many companies were aware of their need for packaging innovation and informed of the available technological opportunities. However, there were some practical implications; the majority did not have a clear understanding of their needs in relation to packaging innovations. These findings highlight the importance of potential and latent demands for innovation and the role of collaborations between research institutions and organizations.

Smart packaging was also addressed by Chen et al. (2020), who reported that packaging systems have evolved due to the integration of emerging electronics, wireless communication, and data cloud solutions.

The authors introduced the concept of integrated food supply chain management, which is fundamental for understanding the tactic and operational components that can improve product traceability throughout the production chain. They discussed the impact of smart packaging on reducing FLW (with the use of sensors, for example) and the potential challenges in manufacturing and deploying smart packaging systems, as well as their disadvantages about costs and sequences in the food supply chain (Chen et al., 2020).

With a focus on agrifood supply chain companies, Ciccullo and Bartezzaghi (2021) investigated the technology portfolio and its detailed objectives for FLW prevention (forecasting, monitoring, clustering, shelf-life extension, product quality, and value addition) by conducting semi-structured interviews with 34 technology providers. The authors argued that these objectives could be reached through different forms of collaboration, such as continuous technical assistance and consulting for data elaboration and analysis or total data sharing and co-design. Finally, the adoption of different technological options may drive vertical collaborations between technology adopters and other segments to combat FLW with a coordinated supply chain effort (Ciccullo; Bartezzaghi, 2021).

Kleineidam (2020) conducted a comprehensive systematic literature review and open-ended interviews with experts, combining empirical and scientific perspectives, to identify the objectives of the implemented FLW measures. The results revealed the importance of increasing cooperation and network transparency within a company and along the entire chain of value. Furthermore, it was found that creating transparency increases value globally, as it can reduce food losses (Kleineidam, 2020).

Islam et al. (2021) showed that traceability technologies have great potential to improve sustainable performance in cold food supply chains by reducing losses. The proposed method was applied in four case studies using data collected from the literature and interviews with experts. The approach can help decision-makers, such as operators of food businesses and technology companies, to identify which combination of technologies best fits a given food supply chain and reduces food loss at a minimal cost.

4 FINAL REMARKS

This systematic review of the literature showed that the United States currently stands out regarding research in food waste, food loss, FLW, sustainability, supply chain, food safety, and primary production, food, and food systems. Brazil, on the other hand, focuses mainly on FLW and its relationship with the supply chain. The journal *Sustainability* is one of the most relevant sources of scientific production on the topic, encompassing different aspects of sustainability associated with FLW.

With regard to the three research questions raised here, the most prominent factors were theoretical approaches to analysing the environmental impacts of the food life cycle, supply chain and stakeholder action, weight estimates of food losses, circular economy, and sociotechnical transitions. From the point of view of governance, the cited authors indicated multi-lateral and multi-dimensional approaches, collaborative actions between institutions and sectors, and increased communication and cooperation between different productive agents. Among organizational and inter-organizational actions, packaging systems, cooperative solutions, transparency within companies and along the food chain, and implementation of electronic traceability systems were found to be the most applied resources.

Finally, this article discussed little-explored perspectives, such as the adoption of theories and governance practices in the supply chain. Several disciplines were incorporated, constituting a multidisciplinary approach that includes aspects of Economics, Environmental Science, Logistics, Nutrition, and Technology. The findings provided a comprehensive view of the causes and consequences of FLW. It was possible to identify significant gaps in the literature and suggestions for future research, such as integrative actions between stakeholders and public policymakers to mitigate FLW. Another original aspect of this study was the critical examination of the adopted methodologies.

There is a need for practical and innovative approaches, homogeneous data validation, and standardized methods that can be applied in different countries and organizations, without disregarding their specificities and cultures.

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