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Food waste management: An analysis from the circular economy perspective

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Abstract

Our study aimed to analyze how the scientific community understands and investigates the management of food waste and communicates in top production and operations journals. The understanding of the available literature encourages relevant insights to outline new ways and strategies for reducing food waste.

KEYWORDS
cycle closed systems, harnessing resources, sustainability

1 | INTRODUCTION

Society constantly lives with antagonistic aspects; sometimes those aspects are so antagonistic that they become complex dilemmas and require scientific analysis to find ways and alternatives for their management, specially to identify the potential of circularity of different materials (Cooper, Ryan, Syndergaard, & Zhu, 2020) including innovation alternatives (Horbach & Rammer, 2020; Van Wassenhove, 2019). This is the case with food waste (Hebrok & Heidenstrøm, 2018). On the one hand, there is efficient production (Hopewell, 2013), with high levels of productivity, technology, nutritional potential, and quality (Mapa, 2019). On the other hand, there is still an exaggerated waste (Ferrazzi, Ventura, Balzaretti, & Castrica, 2019), excessive and unacceptable food chains (Wessolovski, 2019), which, according to the Food and Agriculture Organization (FAO, 2011), corresponds to a third of all that is produced is wasted or becomes garbage. According to Krishnan, Agarwal, Bajada, and Arshinder (2019), food waste is considered one of the biggest changes needed for the safety of global food chains, as 20%–30% of food waste occurs postharvest, including food waste generation from hospitals (Melikoglu, 2020). In addition to food waste, food industries and the food supply chains sector adopt huge volumes of plastic crates, cardboard boxes, and wooden boxes that generate a lot of waste (Accorsi, Baruffaldi, & Manzini (2020).

Apart from wasting food, natural resources are being depleted to supply food supply chains (Gobel, Langen, Blumenthal, Teitscheid, & Ritter, 2015). Virgin natural resources, fertilizers, fuels, and water are being extracted to supply an inefficient system (Krishnan et al., 2019). In addition, poorly managed waste also causes damage to people's health, quality to live, such as well-being, welfare, and damage to natural ecosystems (Gokarn & Khutamnalayam, 2017).

Based on this antagonism between production and waste, this study aims to analyze how the scientific community understands and investigates the management of food waste and communicates in top production journals and operations. Moreover, we identify advances in the field that pertain to the precepts of the circular economy. It is important to perform this analysis in search of scientific elements that can contribute to the management of food waste in emerging countries. As a case study, we investigate Brazil, because it demonstrates many regional asymmetries and needs to alleviate the hunger of many people who are in a vulnerable social and economic situation. Brazil also aims to contribute toward meeting the 2030 Sustainable Development Goals (SDG, 2015), especially 2, zero hunger; 12, responsible consumption and production; 17, partnerships toward the goals.

There are several studies that emphasize reducing food waste. For example, Santos and Escrivão Junior (2019) analyze engagement

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strategies to combat food waste in hospitals. Deliberador (2019) examines food waste in Brazilian university restaurants. Other studies explore a range of related topics, including the bottlenecks where food is wasted (Zanini, 2013), the nutritional adequacy of meals served in a kindergarten and food waste (Souza, 2016), guidelines to minimize food waste in family units (Wessolovski, 2019), loss and waste of food at harvest and postharvest (Silva, 2017), the management and recovery of sustainable organic waste (Ng, Yang, & Yakovleva, 2019), and waste management in the horticultural sector (McCarthy, Capetanaki, & Wang, 2019). Although the scope of the studies is different, everyone's central concern is the same—to reduce food waste and make some uses for more efficient circularity of resources, by regenerative and restorative systems.

The theoretical gap to which this study seeks to contribute is the understanding of the written communications of top journals and their perspectives of analysis, understanding, and evaluation of food waste. Based on this level of interpretation, it seeks to find avenues for the advancement of food waste management strategies enablers by the principles of the circular economy in emerging countries, particularly in Brazil. The emphasis is on resource recovery practices for food waste reduction, extension of life, regeneration, and use of virgin materials.

The justification for choosing the theme is associated with the complex and immense advances that are needed to manage food waste, either by identifying the root cause of the problem or by measuring the levels of waste or the tools, methodologies, and strategies for managing it. The social contribution of the study comprises offering insights to promote advances in the field of food waste for the Brazilian context aligned with the original circularity principles of the circular economy. Brazil as an emerging country, with continental geographic distances, can teach a lot about how to efficiently manage food waste. Because it has very peculiar characteristics, it was chosen as a target for presenting a research agenda to advance the theme.

In addition to this introduction, the paper presents a theoretical section on food waste management and principles of circular economy. This section seeks to present an overview of the possible links between the constructs and recent studies of the theme. The following section describes the methodological path taken. Next, the data are presented and analyzed, contemplating an analysis and reflection on the main evidence mapped by the study. Finally, considerations containing implications for actors in the food production chain and the references consulted are presented.

2 | FOOD WASTE MANAGEMENT AND CIRCULAR ECONOMY

Food waste comprises the disposal that occurs specially at the end of the production chain system and losses associated with the beginning of the chain (Deliberador, 2019). It is estimated that approximately one third of the world's food is unfortunately lost or wasted throughout the supply chain (FAO, 2011). To minimize food waste, the circular economy plays a relevant role. The circular economy, according to EMF (2015), adopts the following principles:

a. Preserves and increases natural capital. In this regard, capital consists of the use of natural and renewable resources from which the best possible performance is extracted. Resource extraction reduces costs and extends the period of a product's best use.
b. Optimizes resource production. When transformed resources are reused, reprocessing and reintroducing them creates new production chains. This step gives new life to obsolete products that are no longer useful in their current format and are considered garbage. Therefore, by means of the assumption of circularity, the potential for the use of resources is expanded, and something useful is created from something once considered discarded.
c. Fosters process effectiveness. Mechanisms for the management of natural resources (water, soil, and air), employ actions that increase the circularity of these materials. Various pollutants that may be generated can be mitigated immediately. Therefore, the emphasis is on producing results by optimizing the use of resources through their constant circularity.

Circular economy principles contribute to efficient resource management by extending the life and use of a product through including some resource recovery processes and circularity of materials alternatives (EMF, 2015). Reuse and recycling are also important waste reduction mechanisms (Krishnan et al., 2019). In particular, waste can be transformed from one supply chain and become an input that feeds other production chains. This transformation occurs through use of biological cycles, natural decomposition, and through including technical cycles, including remanufacturing, also alternative to refurbishing, and recycling and to mitigate waste (Sehnem, Campos, Julkovski, & Cazella, 2019). Finally, to create upgrade for the material, restorative and regenerative processes should be adopted (Morseletto, 2020). Finally, low technological level (cheaper and accessible) should be used to improve environmental performance (Moni, Mahmud, High, & Carbajale-Dale, 2019).

3 | METHODOLOGICAL PROCEDURE

The systematic literature review (SLR) was elaborated by conducting a research that look for articles in top journals of operations and production, which have an index equivalent to 4*, 4 and 3, in the "Association of Business School Ranking" (ABS) in addition to the journals on the "The University of Texas and Dallas – UTD Top 100 Business School" list. These journals, as evidenced in Exhibit 1, were chosen because of their worldwide recognized scientific rigor. Both listings consult the reference journals with high impact factor and scientific notoriety in the area of operations and production. The articles were searched on April 11, 2020. The search terms adopted for the search were "food waste" or "food wastage." The search was carried out without defining a specific time period. That is, for all papers found, the inclusion and

EXHIBIT 1 Top journals mapped for research

Journals	Which ranking does it belong?	ABS ranking	Number of articles found
International Journal of Production Economic (IJPE)	ABS* List	3	40
Production, Planning and Control (PPC)	ABS List	3	18
International Journal of Production Research (IJPR)	ABS List	3	15
Production and Operations Management (POM)	ABS List/ UT Dallas	4	4
Operations Management (OM)	ABS List/ UT Dallas	4*	4
International Journal of Operations and Production Management (IJOPM)	ABS List	4	3
Journal of Supply Chain Management (JSCM)	ABS List	3	2
Journal of Operations Management (JOM)	ABS List/ UT Dallas	4*	2
Manufacturing and Service Operations Management (MSOM)	ABS List/ UT Dallas	3	2
Supply Chain Management (SCM)	ABS List	3	1
Total of articles	91		

*Association of Business Schools.

exclusion criteria provided for in our research protocol were applied, regardless of the year in which this paper was published.

The StArt tool was adopted to classify articles according to focus, quality, article scope, emphasis on food waste and specificities of food waste. The protocol used in this research is based on the propositions of Tranfield, Denyer, and Smart (2003), who divide the process into three main steps: (1) "Planning the Review," (2) "Conducting a Review," and (3) "Reporting and Dissemination." In the first stage, the objectives and the research problem are defined, and from them, the databases were selected for the collection of articles.

Then, the 91 articles obtained were downloaded from their respective databases (publication and summary information) and inserted into the StArt tool, in which the Systematic Literature Review (SLR) protocol was outlined and subsequently segregated between articles. From reading the title, keywords, and abstracts of each sample paper, a classification ("accepted," "rejected," or "duplicated") was assigned. This classification was based on the inclusion and exclusion criteria defined by the authors in the research protocol.

The second step, executing the review itself, applied the inclusion criteria to the 91 articles, consisting of:

a. Focus: addressing food waste and/or addressing food waste prevention and reduction practices.
b. Quality: peer-reviewed scientific journal, recognized for its scientific seriousness.
c. Scope of the article: aligned with food waste management, mapping, diagnosis, indicators, and strategies to act on food waste.
d. Alignment with the researched theme: the study has emphasis on food waste.
e. Contribution of the study: highlighting advances in the management and regeneration of food waste. Show a clear contribution to the field of study by presenting new ideas, discoveries, and linking to existing knowledge.

All articles that did not meet the criteria mentioned above were excluded or rejected. In addition, articles appearing on more than one basis were automatically identified and categorized as "duplicated" by StArt itself. Subsequently, four reading priority levels (very high, high, low, and very low) were assigned to the 31 accepted articles, which allowed us to list which studies were most aligned with the objectives of the present study. Thus, 32% of articles (10) were classified with low reading priority, 65% (20) with high reading priority, and 3% (1) with very high priority. Only articles with high and very high priority were selected for full reading and subsequent data tabulation. The justification for choosing these articles for full reading is associated with the level of alignment of these texts with the purpose of this study. These articles met the inclusion requirements of the study.

To tabulate the data, 24 codes were created that should be identified in each of the articles, as indicated in Exhibit 2. As the articles were read, they were also coded, which, according to Miles, Huberman, and Saldana (2014), is not a purely technical activity but the beginning of the process of analyzing a research.

The process described above, simplified in Exhibit 3, resulted in the sample analysis of 20 articles, all aligned with the theme and research problem.

4 | DATA PRESENTATION AND ANALYSIS

4.1 | Profile of the articles analyzed

Exhibit 4 shows the distribution of articles over the years. The years 2017 and 2019 stand out for having the largest number of articles analyzed (7). The first year features a Special Issue on Closed-loop supply chain: economics, modeling, management, and control on the *International Journal of Production Economics.* Also, in 2019, the United Nations initiated support programs to reduce food waste.

EXHIBIT 2 Defined codes for article data tabulation

Codes	Code description
Title of the article	What wastes were mapped?
Journal	What indicators of waste were mapped?
Author(s) name	What causes for the source of waste were described in the article?
Universities where authors are linked	What options for managing / reducing / preventing waste were described in the article?
Country where study was done	What tools/methodologies for waste measurement were described in the article?
Objective of the study	Type of study done
Theory or theoretical approach used to elaborate the study	Main conclusion of the study?
Where was the study done?	Implications of study results for theory
With whom was the study done?	Implications of study results for practice
How were the data collected?	Study limitations
How were the data analyzed?	Recommendations for future work
How does the study relate food waste to the circular economy?	Additional Information

EXHIBIT 3 Steps for obtaining the sample of articles for analysis

Steps	Number of articles
Extraction databases	91
Selection	31
Selection of accepted articles (high and very high)	21
Coding	21

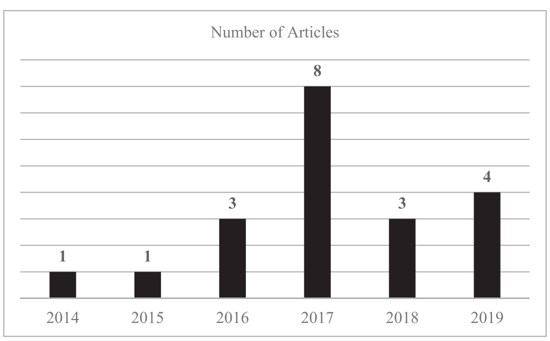

EXHIBIT 4 Total articles published per year

EXHIBIT 5 Journals that published on the theme analyzed

Journals	Number of articles	Impact factor	ABS ranking	Quality
IJPE	11	4.998	3	A1
PPC	5	2.369	3	A1
IJOPM	1	4.111	4	A1
SCM	1	4.296	3	A1
IJPR	1	3.199	3	A1
POM	1	2.59	4	A1
MSOPM	1	2.667	3	–
Total	21		–	–

Exhibit 5 presents the journals that published the analyzed articles. *The International Journal of Production Economics* was highlighted, in particular, for having published a Special Issue related to the topic under analysis in this study.

Regarding the type of study, the following approaches were mapped:

- **Case study**: 13 articles analyzed (Banasik et al., 2016; Belavina, 2020; Birisci & McGarve, 2016; Li, You, & Wu, 2017; Choi, Guo, Liu, & Shi, 2019; Farooque, Zhang, & Liu, 2019; Martins, Melo, & Pato, 2018; Sgarbossa & Russo, 2017; Tromp, Haijema, Rijgersberg, & van der Vorst, 2016; Veldhuis et al., 2019; Vlachos, 2015; Vlajic, Mijailovic, & Bogdanova, 2018; Wikoff, 2017; Xiong, Ng, He, & Fan, 2017).
- **Multiple case study**: 4 articles analyzed (Batista et al., 2019; Broekmeulen & van Donselaar, 2017; Kiil, Dreyer, Hvolby, & Chabada, 2017; Mena, Terry, Williams, & Ellram, 2014).
- **Simulation**: 1 article analyzed (Buisman, Haijema, & Bloemhof-Ruwaard, 2017).
- **Literature review**: 1 article analyzed (Govindan, 2017).
- **Theoretical essay**: 1 article analyzed (Haijema & Minner, 2018).

This shows that the theme is still under consolidation. Qualitative studies and understanding/analysis of an organizational context or theoretical studies prevail. Thus, it is noticeable that there is opportunity for advances in this field of knowledge, especially with monitoring of the maturity stage of the theme and the most appropriate type of study for consolidated subjects.

Exhibit 6 shows that the United Kingdom is the leader in studies in the field of food waste according to the sample of articles analyzed.

EXHIBIT 6 Countries where the analyzed studies were performed

Countries	Absolute frequency	Relative frequency
The United Kingdom	4	19%
The USA	3	14%
The Netherlands	2	10%
China	2	10%
Europe	2	10%
Hong Kong	1	5%
Hungary and Romania	1	5%
Italy	1	5%
Norway	1	5%
Denmark	1	5%
Portugal	1	5%
Singapore	1	5%
Doesn't mention	1	5%
Total	21	100%

Note: The sum of the values may differ from the total shown due to rounding.

However, the theme has attracted scholarly attention from several different countries.

4.2 | Main evidence mapped in the analyzed studies

Exhibit 7 shows the most relevant result chosen in the articles.

Exhibit 8 shows that a variety of theoretical approaches are used to conduct studies on food waste. However, the adoption of administrative theories is still timid. Mentions were made of RBV (Farooque et al., 2019), NRBV (Mena et al., 2014), institutional theory (Farooque et al., 2019), contingency theory (Farooque et al., 2019), and stakeholder theory (Wikoff, 2017). This shows that researchers are interested in resources, the environment, stakeholders, and adaptability. They can move forward from theories that allow them to analyze context, scope, innovativeness, strong sustainability, and actors who engage in supply chains to make them more efficient.

Regarding the objectives of the studies analyzed, note that because it is an emerging theme, the studies tend to be qualitative or theoretical. From the qualitative perspective, there is a signaling for the understanding of specific cases through the description and interpretation of social phenomena and specific organizational scenarios. The theoretical studies include the systematic review of the literature and elaboration of the theoretical framework.

4.3 | Codification of the main purposes of analyzed studies

Essentially, the objectives of the analyzed studies can be categorized as follows:

- **Studies focused on diagnostics**: as in the case of food-sharing platforms for the supply chain and its agents, for consumers and for the environment (Choi et al., 2019); sustainable management of the sustainable supply chain in the food industry (sustainable consumption and production) (Govindan, 2017).

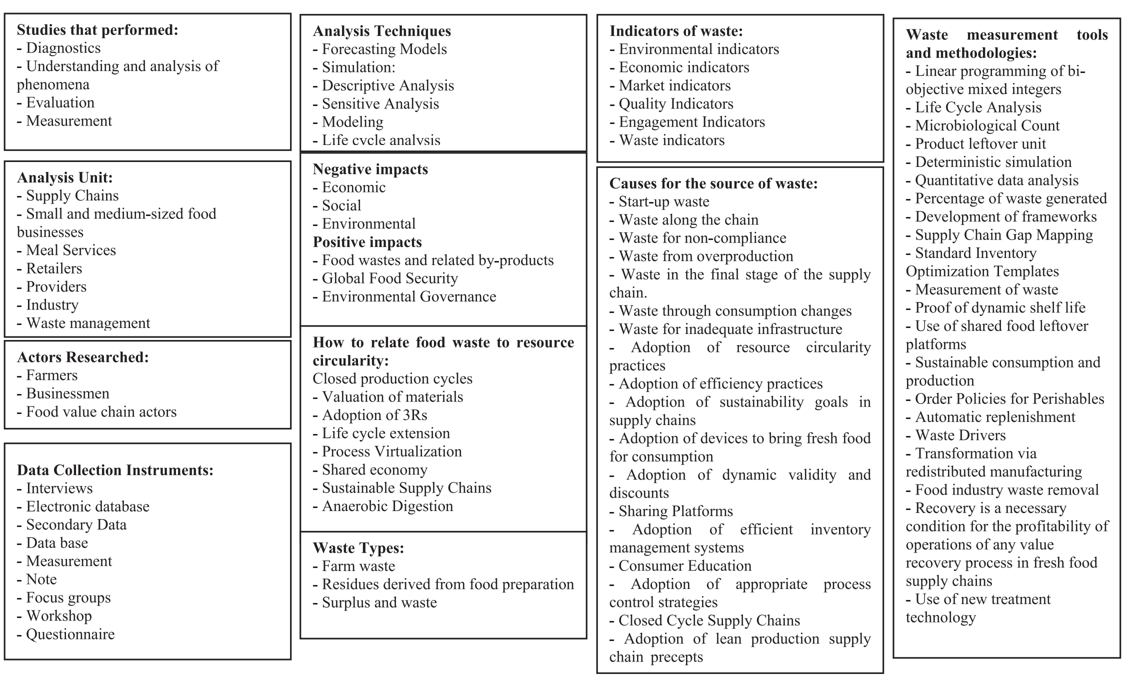

EXHIBIT 7 Synthesis of the main evidence mapped in the analyzed studies

EXHIBIT 8 Theory and theoretical approaches addressed in the analyzed studies

N.	Theoretical approaches
1	Automatic replenishment programs in the food supply chain
2	Model of a refrigerated supply chain
3	Problem description and modeling structure
4	Stakeholder theory
5	Life-cycle assessment
6	Reduction of food waste in the retail supply chain
7	Circular economy
8	Supply chain sustainability
9	Resource-based view
10	Dynamic capabilities
11	Contingency theory
12	Institutional theory
13	Circular supply chain
14	Closed-loop supply chains
15	Multicriteria decision-making models in agri-food supply chains
16	Resource recovery
17	Closed circuit supply chain
18	Dynamic lifetime
19	Estimated deficit and environmental costs associated with food waste due to overproduction
20	Perishable inventory management
21	Lean thinking, leadership, culture
22	Maturity and knowledge management perspective
23	Natural resources-based company vision
24	Issue definition policy and inventory age
25	Industrial redistribution and food–energy–water
26	Sustainability in food supply chain management
27	Food supply chains, remnant inventory, management and platform operations in the shared economy

- **Studies aimed at understanding and analyzing specific phenomena**: through the use of specific technical expertise (Batista et al., 2019); understanding of favorable policies for food production (Birisci & McGarve, 2016); redesign of a multitier food bank's supply chain for collecting food donations and distributing them to charitable agencies (Martins et al., 2018); waste in food supply networks and inefficient use of natural resources embedded in wasted food products (Mena et al., 2014); causal relationships between barriers to circular food supply chains; and the environmental impacts of stakeholder-driven sustainable procurement policies in institutional settings (Wikoff, 2017).
- **Studies aimed at assessing**: the economic and environmental performance of cycle-closing technologies in food supply chains (Banasik et al., 2016); the performance of departments in supermarkets that favor the reduction of food waste (Broekmeulen & van Donselaar, 2017); simulation in order management (Haijema & Minner, 2018); interventions to prevent wastage of refrigerated food at points of sale and to assess the impact of these interventions on a specific case of fresh lettuce cut at a Dutch point of sale (Tromp et al., 2016); under what circumstances retailers should choose traditional packaging to save packaging costs, under which circumstances they should choose sustainable packaging to extend shelf life and reduce waste, and how the choice depends on the operating environment (Li, Yu, & Wu, 2017).
- **Measurement studies**: such as the analysis of the effect of Dynamic Life Discount on a retailer's replacement and its performance in terms of waste, profit, scarcity, and product quality (Buisman et al., 2017); manual versus automated replacement and its implications for food waste metrics (Kiil et al., 2017); analysis of three fresh food supply chain networks, considering residual product value, quantities available for recovery, recovery value, and markets for recovered products; of the effect of interactions on the initial state of the system (Vlajic et al., 2018).
- **Studies focused on prospecting new scenarios**: how to create a sustainable closed-loop supply chain (CLSC) model using and recovering meat processing waste (Sgarbossa & Russo, 2017); assessment of opportunities and challenges for redistributed food manufacturing and their consequences in the water, energy, and food nexus (Veldhuis et al., 2019); examining the adoption of lean thinking in the food supply chain (Vlachos, 2015).

Regarding the analysis unit of the studies under analysis, the following categories are:

- **Supply chains**: mushrooms (Banasik et al., 2016), meat, fresh lettuce, bread, tomato paste.
- **Small- and medium-sized food businesses**: distillation of fruit puree; seasonal cake making; dry pasta making; bakeries and retail stores; food catering; and canning vegetables (Batista et al., 2019).
- **Meal services**: university restaurants (Birisci & McGarve, 2016).
- **Retailers**: supermarket chains, retail outlets (Buisman et al., 2017), and grocery stores (Kiil et al., 2017).
- **Suppliers**: rural producers, Portuguese Federation of Food Banks (FPBA) (Martins et al., 2018), food supply networks (Mena, Terry, & Ellhram, 2014); of tea (Vlachos, 2015).
- **Industry**: Agri-food (Xiong et al., 2017).
- **Waste management**: urban solid waste management system (Broekmeulen & van Donselaar, 2017).

Regarding the actors researched for the development of the analyzed studies, the analysis categories are:

- **Rural producers**: suppliers (Choi et al., 2019), namely, mushroom growers (Banasik et al., 2016), fruits (Broekmeulen & van Donselaar, 2017), and vegetables (Vlachos, 2015).
- **Entrepreneurs**: decision-makers, executives, managers, bosses, and business owners (Li et al., 2017).
- **Food value chain actors**: subjects involved in bread and pasta production (Veldhuis et al., 2019); retailers (Buisman et al., 2017),

network actors (Mena, Terry, & Ellhram, 2014), and purchasing managers (Wikoff, 2017).

Concerning the data collection instruments, we highlight:

- **Interviews**: most usual are the interviews with industrial partners and collaborating food processing scientists. The purpose is to quantify the environmental impact of all activities and processes in the mushroom supply chain (Banasik et al., 2016); with managers (including owners / managing directors) (Batista et al., 2019); store manager, warehouse manager, forecasting officer (Kiil et al., 2017); retailers (Broekmeulen & van Donselaar, 2017).
- **Electronic database**: production, sales, and inventory management data (Birisci & McGarve, 2016); retailer's database; access to the solid waste system (Xiong et al., 2017).
- **Secondary data**: very common to meet average profit per week, waste, scarcity, and microbiological count of products sold (Buisman et al., 2017) and order policy (Haijema & Minner, 2018).
- **Databases**: Scopus and EBSCOhost (Haijema & Minner, 2018).
- **Measurement**: sales and waste generated (Kiil et al., 2017) and food temperatures (Tromp et al., 2016).
- **Observation**: on-site food management practices (Kiil et al., 2017).
- **Focus groups**: with actors in the food value chain (Veldhuis et al., 2019).
- **Workshop**: with actors in the food value chain (Veldhuis et al., 2019).
- **Questionnaire**: applied to key informants (Li et al., 2017).
- **Action research**: (Vlachos, 2015).

The analysis techniques adopted were:

- **Forecasting models**: multiobjective mixed integer linear programming (Banasik et al., 2016); forecasting models (Birisci & McGarve, 2016), stochastic dynamic programming (Haijema & Minner, 2018), Fuzzy DEMATEL technique (Farooque et al., 2019).
- **Simulation**: simulation-based optimization (Buisman et al., 2017) and simulation models (Tromp et al., 2016; Xiong et al., 2017).
- **Pattern matching**: (Veldhuis et al., 2019).
- **Descriptive analysis**: it is common for this technique to be used to illustrate process management practices and supply chain processes; analysis within the case and between cases with interviewee triangulation (Mena et al., 2014) and case triangulation (Vlajic et al., 2018).
- **Sensitive analysis**: (Choi et al., 2019).
- **Modeling**: (Li et al., 2017).
- **Life-cycle analysis: (**Wikoff, 2017).
- **Triangulation of data: (**Sgarbossa & Russo, 2017).

4.4 | Negative and positive impacts of food waste management

The negative impacts of waste were categorized as follows:

a. Negative impacts:
b. **Economic impacts**: spending on material (Vlachos, 2015), waste transportation (Kiil et al., 2017; Martins et al., 2018), and high costs for retailers to manage waste (Broekmeulen & van Donselaar, 2017; Martins et al., 2018; Sgarbossa & Russo, 2017).
c. **Environmental impacts**: environmental burden (Birisci & McGarve, 2016), CO_2 emission (Birisci & McGarve, 2016), environmental damage (Vlachos, 2015; Govindan, 2017), greenhouse gas (GHG) emissions (Sgarbossa & Russo, 2017), and landfill waste (Kiil et al., 2017; Martins et al., 2018; Sgarbossa & Russo, 2017).
d. **Social impacts**: social stigma of waste (Broekmeulen & van Donselaar, 2017; Martins et al., 2018; Sgarbossa & Russo, 2017; Vlachos, 2015) and hunger (Govindan, 2017).

Therefore, it is clear that the negative impacts are associated with the increase in costs that burden supply chains. In addition, environmental damage impacts society in general and contributes to reducing people's quality of life. The mapped social impacts demonstrate that food waste reduces the existing asymmetry between those who have plenty and full access to food and those who suffer from malnutrition and do not have adequate conditions to access healthy food. This is a serious aspect, which contributes to increasing malnutrition, the health problems of the population, and the cost of public health and inequalities.

a. Positive impacts:
b. **Food wastes and related by-products**: these can be valuable resources for other processes within or outside the supply chain from which they were originally generated (Batista et al., 2019).
c. **Global food security**: with safe food risk management strategies (Farooque et al., 2019; Veldhuis et al., 2019).
d. **Environmental governance**: with significant environmental impacts from the efficient management of food waste (Farooque et al., 2019).

Therefore, it is evident that there are initiatives that enable supply chains to obtain superior returns through efficient management of food waste. This occurs through governance, risk management, and adherence to the principles, practices, and premises of the circular economy. These are the initiatives that need to be promoted and stimulated. They are the ones that will contribute to increase efficiency in the management of food waste. They will contribute to the optimization of processes and will generate innovative, disruptive, and surprising alternatives for society. For example, sneakers made using fruit peels and must from the fermentation of wines and beers used in the cosmetics sector. These are examples that strengthen the circular economy's potential for progress in food waste management.

Regarding how to relate food waste to the circularity of resources, the following categories of analysis emerge:

- **Closed production cycles**: adoption of the closed-loop in supply chains (Banasik et al., 2016; Choi et al., 2019; Sgarbossa & Russo, 2017).

- **Recovery of materials**: implies waste reduction (Farooque et al., 2019) either through disposal through use in new products or new applications for waste (Vlajic et al., 2018).
- **Adoption of 3Rs**: reduce, reuse, recycle food waste, and by-products (Batista et al., 2019).
- **Life-cycle extension**: which has a positive impact on reducing greenhouse gas emissions (Wikoff, 2017), minimizing CO_2 emissions, and the social cost of carbon (Birisci & McGarve, 2016).
- **Process virtualization**: application to bring suppliers and purchased together, to adjust product freshness—delivery close to product consumption time (Buisman et al., 2017).
- **Shared economy**: to stimulate exchanges (Choi et al., 2019; Martins et al., 2018).
- **Sustainable supply chains**: adoption of sustainability practices that ensure the best use of food in all links of the production chain (Govindan, 2017). An example is Blue City, located in Rotterdam, the Netherlands, where several circular businesses were created, such as the use of coffee beans for mushroom cultivation, the use of CO_2 emissions for the cultivation of spirulina—a protein-rich seaweed that can be consumed by humans and animals—and using discarded fruits to produce leather (Blue City, 2017; Veldhuis et al., 2019). These examples contribute to the extension of the product life cycle (Veldhuis et al., 2019).
- **Anaerobic digestion**: for organic waste management (Xiong et al., 2017).

As for the types of waste, these categories of analysis emerge:

- **Farm waste**: if properly managed they can be used for mushroom production (horse and chicken manure are some of the ingredients that can be used for mushroom substrate production) (Banasik et al., 2016).
- **Residues derived from food preparation**: fruit puree, cake making, dry pasta making, food catering, vegetable manufacturing (Banasik et al., 2016); chips, meat ravioli, chicken sandwich (Wikoff, 2017); fruits, vegetables, fresh meat (Buisman et al., 2017; Mena et al., 2014; Tromp et al., 2016); salmon, eggs, trout, mayonnaise, salads, butter, cheese (Kiil et al., 2017); precut lettuce (Tromp et al., 2016); bread paste (Veldhuis et al., 2019); tomatoes (Batista et al., 2019; Birisci & McGarve, 2016; Broekmeulen & van Donselaar, 2017; Veldhuis et al., 2019).
- **Surplus and leftovers**: derived from food preparation and not immediately consumed (Choi et al., 2019).

Regarding the indicators of waste mapped in the studies analyzed, the following stand out:

- **Environmental indicators**: total energy loss (Banasik et al., 2016), environmental cost (Birisci & McGarve, 2016), and energy self-sufficiency (Sgarbossa & Russo, 2017).
- **Economic indicators**: financial performance (Broekmeulen & van Donselaar, 2017), quantity of products, disposal cost (Birisci & McGarve, 2016), and profitability indicators (Sgarbossa & Russo, 2017).
- **Market indicators**: sales, inventory levels (Kiil et al., 2017).
- **Quality indicators**: shelf life (Tromp et al., 2016) and types of packaging used for food storage (Wikoff, 2017).
- **Engagement indicators**: donors who deliver food items to food banks; donors requiring food items to be collected by food banks; donors providing financial donations to food banks; food banks existing at the beginning of the planning horizon; potential locations for locating new food banks; charities serviced by food banks at the beginning of the planning horizon; charities on hold; agencies awaiting food assistance; food families; individual food items belonging to the family; discrete capacity levels for storage areas / transportation resources (Martins et al., 2018).
- **Waste indicators**: percentage of waste in the supply chain (Mena et al., 2014); waste due to natural quality deterioration (Tromp et al., 2016).
- The causes for the origin of waste were mapped, which are associated with:
- **Start-up waste**: in agricultural production. At harvest, residues may include crops damaged during harvest or edibles left in deteriorating fields (Kiil et al., 2017).
- **Waste along the chain**: in handling, postharvest storage; in processing; classification, in the distribution, retail, and consumer segments; surpluses; fixed order unit. Postharvest food waste includes food loss due to decreased quantity or quality of food and deterioration of perishable foods that deteriorate to the point of inedible or unsafe to consume. In processes such as trailing, drying, primary processing, cleaning, sorting, transportation, distribution and storage, food waste can occur due to loss through inadequate techniques, facilities or infrastructure, process losses, contamination, and mishandling (Kiil et al., 2017).
- **Waste for noncompliance**: because it does not meet the aesthetic requirements of the market (e.g. shape, size, weight, visual presentation, etc.) specified by major retailers; strict selection behavior; at the expiry date; unsold food products; ages of perishable goods in stock; order delivery time; short expiration date.
- **Waste from overproduction**: associated with seasonal effects of supply versus demand.
- **Waste in the final stage of the supply chain**: on consumption. Retail and post-consumer losses include food waste from activities and operations, such as short life cycles that can create confusion about "best before" and "use to" dates for consumers and improper food preparation techniques.
- **Waste by consumption changes**: by climate and by the natural variability of food products.
- **Waste from inadequate infrastructure**: inadequate infrastructure, knowledge and technology, inadequate equipment and logistical problems that are exacerbated by an agricultural and/or decentralized production system.

4.5 | Alternatives to reduce and prevent the generation of food waste

The options to manage, reduce, or prevent food waste identified in the studies are categorized into:

- **Adopting resource circularity practices**: The mushroom supply chain provides an example of an agri-food supply chain in which not the product itself, but the means for growing the product can be reduced, reused, or recycled.
- **Adoption of efficiency practices**: in the use of resources (Choi et al., 2019).
- **Adoption of sustainability goals in supply chains**: set specific goals related to sustainability issues, including a reduction in food waste.
- **Adoption of devices to bring fresh food for consumption**: Improving the freshness of food at retail will reduce the levels of food waste from consumers.
- **Adoption of dynamic shelf life and discounts**: These are effective strategies to reduce food waste by the retailer.
- **Sharing platforms**: to make available for promotional prices or for donation food near the expiration date. Or, distribute the food through the food banks.
- **Adoption of sustainable production and consumption standards**: adopting quality, inputs, processing, and industrialization assumptions in line with sustainability assumptions.
- **Adoption of efficient inventory management systems**: With today's technology, it is possible to track the shelf life of products in stock. This information can be used to make better replacement decisions that reduce food waste without compromising product availability. The need for better ordering policies is supported by increased attention to initiatives that reduce food waste. Using automatic replenishment has a positive impact on reducing food waste and extending the remaining shelf life of some food products or adjusting the available retail stock.
- **Consumer education**: to make consumers more aware when buying, processing, and consuming food.
- **Adoption of appropriate process control strategies**: to avoid waste along the production chain.
- **Closed-cycle supply chains**: enabling end-of-life materials to be reintroduced to provide input for new production chains. Food waste has the potential for power generation and fertilizer, its redistribution to animal feed, donations to charitable organizations, and transparency in the food sector (food production process and environmental printing).
- **Adoption of lean production supply chain precepts**: to reduce waste along the entire chain and simplify processes, making them more agile.
- **Improvement of food waste recycling services**: through the introduction of anaerobic digestion facilities to recycle food waste with better energy recovery, less hazardous emission, and land use.
- **Reduce barriers**: increase resilience between supply chain links and risk management.
- **Apply Last In, First Out, First In, First Out analysis**: to manage food quality more accurately and transparently.
- **Evaluate the type of packaging to be used for storing food**: some types of packaging reduce food waste.

Among the tools and methodologies for measuring waste emerge the following categories:

- **Linear programming model of bi-objective mixed integers**.
- **Adoption of life-cycle analysis**
- **Microbiological counting**: associated with meat quality and food safety.
- **Product leftover unit**: measure leftovers using a standard metric.
- **Deterministic simulation**: Product waste is estimated by deterministic simulation for the next R + L-1 periods, presuming that demand will be equal to average demand.
- **Quantitative data analysis**: to measure the flow of food, with supply, process waste, waste for excess validity and consumption waste.
- **Percentage of waste generated**: to identify mechanisms for continuous improvement and reduction of this waste as well as their reintroduction into new chains.

5 | MAIN CONCLUSIONS

The main conclusions of the studies analyzed were categorized as follows:

- **Development of frameworks**: development of a multiobjective model for production planning and distribution in industrial mushroom production, focusing on waste valuation in the form of a CLSC. It fills the gap pertaining to the need for specific case studies related to logistical concerns of industrial symbiosis. Another elaborate analysis model was the CLSC, particularly in industries for which the development of new research practices and structures such as the food supply industry is becoming urgent.
- **Supply chain gap mapping**: implementing knowledge management to support sustainability initiatives such as food waste and by-product synergies throughout the food supply chain is still far from the operational reality of most SMEs (medium enterprises).
- **Use of standard inventory optimization models**: to address the common production planning problem in the presence of uncertain demand.
- **Measurement of waste**: as a percentage.
- **Proof that dynamic shelf life** is more efficient than discount effect in reducing food waste.
- **Using shared food leftover platforms**: in decentralized supply chains it is beneficial for retailers, suppliers, consumers, and the environment (Choi et al., 2019).
- **Emphasis on the shift and increasing importance of sustainable consumption and production**: focusing on the food industry.
- **Providing a classification of order policies for perishable products**: here two classes of new policies were introduced depending on age of inventory. One policy class is BSP-WS, which is the weighted BSP for older products in stock. The rationale of this policy is to give less weight to products that are most likely to expire. Another policy class increases the order quantity by adding an estimate of product waste to the order quantity. BSP-EW corrects increases order size by the estimated number of products that end up being wasted.
- **The use of automatic replenishment**: has a positive impact on reducing food waste and increasing the remaining shelf life of some food

products. Improvement in automatic replenishment is highest for products with a shelf life between 51 and 110 days where the reduction in food waste exceeds 20% (2% points) for the products analyzed.

- **Several significant causes of food waste are beyond the control of managers across the supply chain**: factors such as climate change, natural variability of food and seasonal effects on supply and demand are exogenous factors. Similarly, regulation, particularly for meat products, was cited as a significant cause of waste.
- **There are several "waste drivers"**: such as low and variable consumer demand, high selection behavior, lead time, a fixed order unit, and a short expiration date. The retailer can adjust the replenishment level of its order policy and the way it rounds to the specified ordering unit, but in doing so, it can at best exchange waste for lack of stock or vice versa.
- **Not all parts of the supply chain have the same potential to be transformed via redistributed manufacturing**: for example, processing of bulk raw materials and a change in the way production is organized will affect many aspects, which often include offsets.
- **Waste removal from the food industry has enormous potential for cost savings and added value**: although 99% of food companies in the European Union (EU) are SMEs, they generate only 45% of value added. Lean tools have been successfully adopted in manufacturing sectors, but there is a high percentage of failures and a lack of a lean paradigm for applying lean thinking in SMEs.
- **The financial value of the recovery is a necessary condition for the profitability of the operations of any value recovery process in the fresh food supply chains**: but not for the corresponding loop itself to occur. Reuse and remanufacturing loops are likely to feed from alternative markets, while recycling loops are likely to feed from fresh food supply chains.
- **To improve the utilization of new treatment technology**: subsidizing the operating cost of the new treatment unit is more effective in the long run than exercising control over the upper limits of operators by the system regulator. In addition, providing residual after-treatment discounts to treatment facilities may benefit service users, not waste treatment operators.
- **Main cause barriers**: first, weak environmental regulation and enforcement, and second, lack of market preference / pressure. Meanwhile, the lack of collaboration / support from supply chain actors is the most important barrier. The root cause and prominent barriers are also identified for each of those involved in the supply chain.
- **Need for better coordination**: between packaging options and inventory decisions, which can increase profitability and reduce waste.

5.1 | Limitations presented by the studies analyzed

Among the limitations of the studies, the following stand out:

- **Limitations for generalizing the results**. The research findings and conclusions reported in the article are valid for organizational and regional contexts beyond those considered in this study. Findings are limited to fresh food supply chains; additionally, the study does not include resource reduction as this is not a value-recovery process. The list of barriers identified in the study was far from exhaustive, although they were sufficient to meet the research objectives.
- **Scope limitations**: Attention was devoted to single-period food products; overproduction cannot be stored and later served as leftovers but instead must be discarded. Likewise, the experimental design was limited to experiments with zero-order costs. When fixed-order costs apply, the classification of policies may change. Future researchers should consider including a limited number of products to investigate the impact on availability and shelf life remaining in food stores. However, the small sample suggests that improvement is possible and future research should examine more products and a longer period of time. The restricted selection of products focused on fresh and short-lived products and ignored broad categories such as canned, dried, and frozen products and wider geographical scopes. The scope of the research is limited to "microlevel" interventions of a technical, logistical, and marketing nature, and the work covers expiration dates and natural quality deterioration. The study was based on scarce literature on lean applications in the food industry.
- **Sample size**: The sample was further limited to store-item combinations with at least three weeks of sales for one year and three deliveries. The sample was based only on the perceptions of institutional purchasing managers on university meal services.
- **Relevant unit of analysis not studied**: The study analyzed responses from various stakeholders in the food supply chain. However, farmers, who are among the major food suppliers, could not be included in the analysis due to data quality issues.
- **Research Design**: Cross-sectional research design found barriers at a given time because it failed to reveal how barriers evolved over time.

5.2 | Recommendations for future studies

Some opportunities to improve studies of food waste:

- Advances with technical tool for measuring food waste: The inclusion of stochasticity in the parameters to arrive at solutions that optimize the expected value of objective functions may be helpful.
- Maturity-level advances: Moving from knowledge management to the sustainability of SMEs in other sectors and regions would supply useful data.
- Advances with tooling to quantify food waste: Future studies may wish to measure food waste across the various links in the production chain. Also, menu items for which overproduction is not necessarily ruled out but may be served at a future meal as leftover may be considered. Quantify the effect of customer withdrawal behavior

EXHIBIT 9 Food waste and circular economy research agenda

Locus of analysis	Suggested studies
Education to minimize food waste	- Conduct a study in state and municipal schools to create communication campaigns and awareness to reduce food waste. - Develop a study focused on the organic products sector and ways to mitigate food waste. - Identify specific segments that have high waste rates and conduct studies to minimize those losses. - Propose public policies and national campaigns to sensitize the Brazilian population to reduce food waste. - Familiarize employees and entrepreneurs with the concept of circular economy and make them aware of its potential. - Create mechanisms to increase resource efficiency and waste reduction and look for ways to make high-risk inputs more circular.
Indicators of food waste	- Measure food waste across all links in the supply chain for different types of food. - Measure food waste in supermarkets. - Measure food waste in hospitals and schools. - Measure food waste in cargo transportation. - Measure food waste with non-quality products. - Create indicators for sustainability goals for food supply chains.
Food-sharing platforms	- Propose sharing platforms and food management dynamics close to expiration date. - Communicate the existence of apps and websites that allow you to share food.
Encouraging adherence to the Mesa Brazil Program	- Disseminate good practices and communication campaigns to join the Mesa Brazil Program for food surplus donation.
Stimulus for sustainable supply chains	- Create sustainability goals for supply chains. - Adherence to sustainability labels and differentiated products. - Create shared value through redesigning products and markets, redefining value chain productivity, and developing local cluster or local productive arrangement. - Analyze the political, economic, social, technological, environmental, and legal factors of different food businesses and their implications for the success of the circular economy.
Stimuli for by-product manufacturing	- Propose strategies to increase the circularity of materials in the supply chains. - Propose mechanisms for adhering to the principles of circular economy in different production chains.
More assertive stock forecasting systems	- Create more assertive inventory forecasting models to avoid excessive retail waste. - Create appropriate decisions to replenish food stock. - Create fresh food inventory forecasting systems based on food consumption algorithms by marketed food type. - Develop studies to understand the demand for fresh food in commercial establishments.
Resource recovery	- Create mechanisms to reclaim resources through redesign, reuse, repair, and redo. - Introduce enabling technologies for material roundness, namely, asset tracking, digitization, big data, and 3D printing. - Proposition of stimuli for renewable energy use.

and weekly patterns on waste level by generalizing waste approximations (for instance, in situations with long lead times and review periods) by comparing the effects of (non) risk strategies. Employing discounts when products near their expiration date will likely impact demand and waste levels, so studying the impact of different ordering behaviors on consumer behavior and waste. Finally, regression analysis might be used on empirical data to find out the extent to which the percentage of waste depends only on package size, shelf life, and average demand, but also on factors such as store, product category, etc.

- Barrier analysis: Future studies may expand the list of barriers under the most relevant theoretical lens identified in this study to suit other research objectives.
- Consumer behavior study: Consumer behavior affects retailer performance. New research focuses more on in-store consumer behavior and investigates topics such as the relationship and replacement of Last In First Out (LIFO) with First In First Out (FIFO).
- Leftover food-sharing platforms: Explore situations where the platform is for-profit and compare whether a profitable platform will outperform a non-profit platform. It will be promising to explore how collaborative consumption (Jiang & Tian, 2018) at the consumer level can help optimize food products.
- Research to achieve sustainability standards: in the supply chain and the food industry.
- Building more efficient search methods and heuristics: to set parameter values. Policy parameter values are correlated and can be explored to make research procedures more efficient.
- How different demand patterns may influence the impact of information sharing: This topic could be further investigated for new empirical insights.

- Identify additional Pareto optimal solutions: for example, applying the ε constraint method, or even its augmented variant, a technique widely used in multiobjective optimization. Focus on designing a custom solution approach to the problem presented in this document, especially when large instances need to be resolved within a reasonable timeframe.
- Identify which categories contribute most to waste: Researchers need to understand the magnitude of specific waste sources to prioritize improvement initiatives to maximize their economic and environmental benefits. Similarly, studies need to better articulate what the possible solutions are and what impact they are likely to have on waste reduction. These are clear opportunities for further research and are likely to have significant practical implications.
- New business models for the CLSC are needed, particularly in industries for which the development of new research practices and structures (such as the food supply industry) is becoming urgent. Future research should investigate other industries (electronics, wood, and heavy industries) from a CLSC perspective to enrich our model. Future studies should focus on the profit indicator, varying supply chain productivity to find out the effect this has on the performance of recovered waste and energy processes.
- Policy implications regarding waste management: for example, by setting limits on acceptable waste percentages, by setting limits on acceptable order policies.
- Interdisciplinary approach: As the challenges in these areas are interconnected, an interdisciplinary approach would be helpful in future research.
- Technique comparison: Compare lean techniques with other systems such as the Kanban card system or other custom systems to track patterns and errors.
- Climate impacts on managing food supply chains: Emphasizing business practices in a region of a developed country in a specific climate zone, future research should address the impact of these factors on managing food supply chains.
- Value recovery in resource reduction: There are only a small number of studies that holistically analyze the effects of value recovery processes on resource reduction. Further studies are needed, and those studies should pursue waste and inventory control.
- More competitive strategies: such as quality of service or route can be considered by the market share model based on utility in the proposed formulation of payment for waste treatment facilities. Second, a more expensive and high-fidelity simulation model can be developed and calibrated using accurate customer preference data to obtain an accurate quantitative analysis of interactions between various treatment unit operators. In addition, the agent-based modeling approach can be applied to enhance the proposed model by generating more managerial insights in a multiunit symbiotic waste management system scenario. Finally, social aspects can be incorporated into the proposed model as a future extension.
- Implications of circular economy legislation as part of its national development strategy: to analyze the weak application of such environmental regulations, considered a major cause barrier in the food sector. Analyze the importance of policy makers addressing issues of bureaucracy, governance, corruption, and environmental education.
- Locus of analysis: Future research should involve collecting data from other stakeholder groups, such as clients themselves, institutional leaders, and other types of stakeholders.

Based on the profile of the studies analyzed, an important and original research agenda for managing food waste in Brazil emerges.

6 | FINAL REMARKS

This study aimed to analyze how the scientific community understands and investigates the management of food waste and communicates in top journals of production and operations. Evidence indicates that studies are characterized by being predominantly qualitative and case studies / multicases. The locus of analysis of the studies is vast. Studies signal the wide range of opportunities that can still be exploited aligned with the precepts of the circular economy to mitigate food waste.

The main theoretical contributions of the study are related to understanding how top journals communicate, investigate, and analyze food waste. The practical contribution is associated with the mapping of recurrent types of food waste and ways to mitigate it based on the precepts of the circular economy. The academic community benefits from this study through the original and unpublished research agenda, to generate advances in the field of food waste knowledge, especially for the Brazilian context.

The limitations of the study are associated with the maturity stage of studies on food waste, which are at an early stage, with a prevalence of qualitative and theoretical studies. This demonstrates the vast scope of opportunities for further study of the subject. Especially with the use of algorithms for the generation of inventory forecasting systems based on the growing variety and volume of fresh food available for sale, the understanding of demand, greater transparency in supply chain management, and appropriate replenishment decisions and forecasting systems will prove fruitful.

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