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Methodologies for characterization, evaluation, and improvement of logistics in the food supply chain

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Abstract: The food supply chain (FSC) is made up of producers, traders and processors who bring the product from supply to demand through logistical processes**.** Food supply chains require specific methodologies for their current diagnosis, evaluation and improvement. Logistics in food supply chain requires to be managed according to its nature. This article identifies the different methodologies through a systematic literature review of publications from 2005 to 2022, using Web of Science, Scopus and Google Scholar search engines, in order to establish the state of the art. As a result of this review, a new taxonomy is proposed and includes the following methodological groups: management, qualitative, quantitative, multi-criteria decision-making (MCDM), statistics, machine learning, mathematical modelling, discrete simulation, system dynamics and others. The methodologies of characterization, evaluation and improvement are classified into two main groups of logistical means and modes. The performance measures most commonly used in the methodologies by the researchers were also identified. From the article, discussions, challenges and trends are generated to identify possible future research and different gaps.

1 Introduction

The characterization establishes an informative and/or descriptive study to establish the situation of logistics in the food supply chain (LFSC). Moreover, the evaluation compares LFSC current status against desired performance measures. In terms of improvement, the aim is to bring logistics in the FSC to a higher performance state.

The logistical modes or processes about how to manage supply, inventories and storage or distribution are relevant in food supply chain; its analysis must consider changes in temperature, relative humidity, perishability, short life cycles, these elements define the use logistical means or resources to be used, such as facilities, transportation, packing and packaging, storage , information and traceability or systems of integrated enterprise resource planning (ERP) from the supplier to the final consumer, as well as government policies, food security, and the effects of natural disasters on food. The means and modes in the LFSC ensure the operation and give rise to the network design, so it is necessary to characterize, evaluate and improve, considering variables, parameters and performance measures such as efficiency, responsiveness and quality [1]. The interaction of each element on the FSC and the relationships between its different agents generate information flows in foods that give rise to designs, which require different methodologies to diagnose, evaluate or improve the LFSC.

The activities that take place in the FSC and logistical processes and resources, the population heterogeneity and uncertainty, are continuous progress elements [2]. The vertiginous market's change requires methodologies and models adjusted to the logistic process, the life cycle and conservation, food transportation with temperature and risk control [3], reverse logistic [4] and the reduction of bullwhip effect [5,6]. Food safety, lack of quality in food supply and the waste generated in the FSC links are caused by shortcomings in logistical modes and means management [7], as reduction of resources and waste generation without proper treatment [8], lack of communication between producer, processor, intermediaries and the consumer, losses due to spoilage from handling, perishability or inadequate structure of the FS, adding also government policies on export and import in a global market [9]. This results in a failure to implement FS management that impacts on quality, food safety and sustainability [10], which significantly reduces the shelf life of food [11], weakening the FSC links in times of disaster or pandemic [12].

Due to these FSCs issues and their logistics processes, there is a need to establish the commonly used methodologies in characterization, evaluation, and improvement for LFSC, their trends and challenges, as well future research. In this systematic literature review, journals information is analyzed to establish the state of art of the most used methodologies.

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2 Methodology

The systematic literature review of LFSC characterization, evaluation and improvement methodologies carried out in: Scopus, Web of science and Google Scholar. A database compiled from 26 research journals was generated, with 123 articles in total, showing that the largest article's number were from databases as Elsevier, Emerald, MDPI, Springer Link and Taylor & Francis. Each article's contribution is considered according to citations, specialized authors, as also seminal, theoretical, and practical articles. To get the information, research included main words, support words and connectors as shown in Table 1.

Table 1 Research methodology

SEARCH	MAIN WORDS	SUPPORT WORDS	CONNECTORS
Scopus	Food Supply Chain - Methodology - Logistics	Characterization – Improvement - Performance - Evaluation	And - Or
Web Of Science	Food Supply Chain - Methodology - Logistics	Characterization - Improvement - Evaluation - Performance	And
Google Scholar	Food Supply Chain- Logistics - Methodology	Characterization - Improvement - Evaluation	And - Or

**Acronyms of words used in the search: Food Supply Chain (FSC), Methodology (M), Logistics (L), Characterization (C), Improvement (I), Evaluation (E), Performance (P)*

The following questions were formulated to guide the systematic literature review: What are the methodologies for diagnosing, evaluating and improving the FSC? What are the characteristics of these methodologies? What are the performance measures used in these methodologies?, and, What are the discussions, trends, challenges and future research regarding the diagnosis, assessment and improvement of FSC?. The information was consolidated according to approaches, topic and specific points regarding LFSC, classified into subtopics, the relationship to logistics areas and social, economic, environmental, or governmental impact. The methodological design steps are presented in Figure 1.

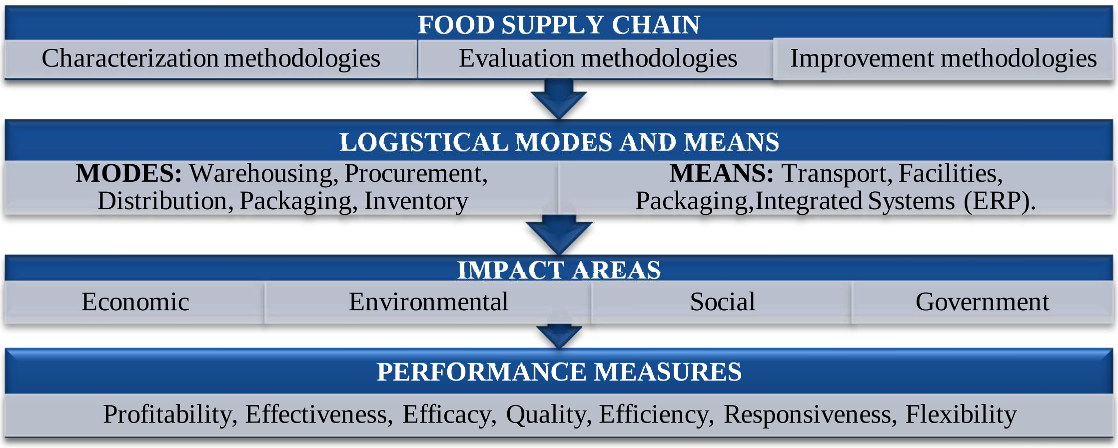

Figure 1 Taxonomy for the analysis of methodologies

The methodologies found present an approach to methods such as decision-making, quantitative analysis, qualitative analysis, and techniques, using different theoretical models and conceptual frameworks. Finally, a taxonomy of performance measures is developed. The methodologies are evaluated chronologically and research trends in LFSC are identified.

3 Methodologies for Characterization, Evaluation, and Improvement of logistics in food supply chain

Based on the systematic literature review, relevant thematic axes were identified for FSC study, some belong before 2010. Those related to current environment dynamics appear from 2017. In India, since 2017, contributions have been made towards integrating FSC with logistics and sustainability through the promotion of new and emerging technologies to address challenges in food security. In China, Turkey and UK, they focus on the use of technologies for traceability, sustainability, and quality, considering different risks in FSC, due to dynamism, environment variability and food life cycles. In Italy and in line with FAO guidelines, the focus is on logistics as a FSC fundamental process for quality and food safety.

In Australia, they focus on use of technologies addressed on risk, vulnerability, and logistics (Imran Ali). Wageningen University in the Netherlands focus on food security and sustainability, where Van der Vorst and his team study FSC and Logistics. Based on the systematic literature review, the classification shown in Figure 2 is proposed, according to each topic and publishing year between 2005 to 2022.

The methodologies compiled in literature are proposed by the authors according to the environment, the complexity of SC management, the characteristics of different foods to be analyzed, the performance measures used, integration level between stakeholders, the logistical processes, as also experience and knowledge of the studied system.

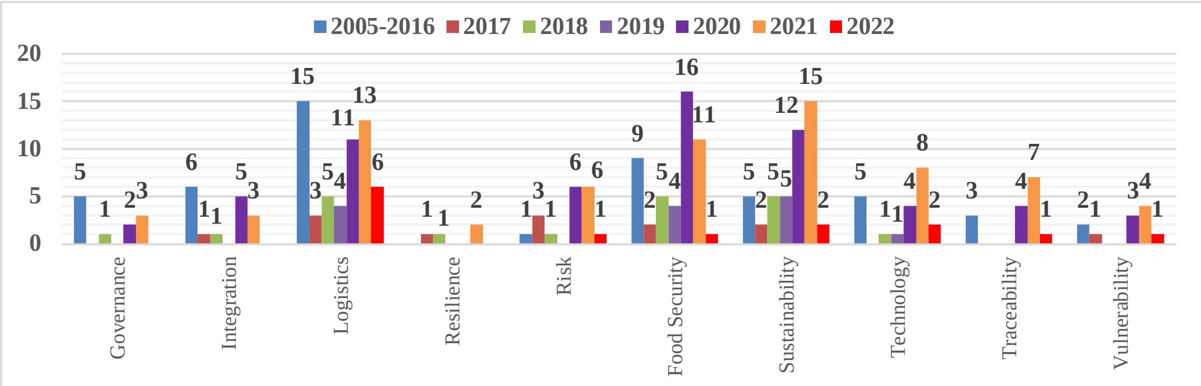

Figure 2 Years versus thematic axes

To establish an appropriate methodology involves proper communication between the parties [13]. The information, logistic and productive flows of the FSC must have connection and coordination, global analysis, responsiveness, reliability and competitiveness, being able to measure and evaluate performance [14].

Identifying the processes involved in the LFSC requires a methodology that works according to the current dynamics, sizing the activities and evaluate the conditions that favor or not their performance [1]. The characterization, evaluation and improvement of the LFSC are linked to the design and configuration of the flows of each of the processes that make up the LFSC [15,16]. The comparison with different SC models or schemes and logistics processes allows establishing a frame of reference and performance measures that determine the past, current and future status. Although the search for economic-financial performance is mainly evident, social, political, environmental and sustainable approaches to CS are appearing [17].

With logistics as a vital axis to proper management supply chain [18], the main methodologies used and the fundamental aspects of each one of these methodologies are presented below, based on the logistic modes and means found in the literature review. The articles consulted on characterization, evaluation and improvement were case studies and development of models that build concepts or constructs and allow modeling of FSC.

3.1 *Characterization methodologies*

The characterization of the LFSC is done analytically or empirically and details each aspect according to the authors' environment. In Table 2, methodologies are divided into management, qualitative, MCDM and statistical.

Table 2 Logistical modes and means in Characterization methodologies

		Management	Qualitative	MCDM	Statistical
MODES	Storage	2	3	5	4
	Supply	0	0	2	4
	Distribution	5	6	2	4
	Packaging	0	1	3	2
	Inventories	0	0	3	3
MEANS	Transport	7	5	6	4
	Packing	3	3	1	1
	Facilities	3	1	3	2
	Enterprise Resource Planning Systems (ERP)	0	0	1	0

3.1.1 Management methodologies

They aim to improve the practices of business processes interacting in the SC. The Balanced Scored Card (BSC) methodology uses costs related to transport, distributions, and deliveries [19]. SCOR is also used, in which the main factor is logistics, facilities and the formulation of sustainable production plant scenarios [20]. The Global Supply Chain Forum (GSCF) methodology generates twenty-four logistics activities for each key FSC business process, integrating supply chain management

(SCM), logistics, business processes, product flow, reverse logistics, logistics risks in cold chain, packing and transport resilience [21], the identification of relevant attributes to describe and represent FSCs with different perspectives or narratives [22].

There are methodologies that work with quality at the core, risks with respect to logistics facilities are addressed through a methodology based on the Quality management model [23], combining quality and risk measures including product lifetime in transport activities [24]. Another approach is structural quality modelling of perishables by analyzing suppliers, customers and logistics processes [25]. Other methodologies [26] work with diagnostic tools such as food safety management system, quick scan audit (QSAM) focused on chain uncertainty addressing material flow in distribution processes, facility analysis and equipment modernity. Empirical models propose activity performance measurement systems, PMS, including real-time transport [27-29]. The reference methodology RAPDtT (Receiving-Storage-Processing-Dispatching-Internal and External Transport) provides a roadmap through a process diagram and covers the logistics operation [30]. Addressing problems holistically is possible in environments of uncertainty, as is the case with the soft systems methodology that is proposed in aspects of sustainability, values and ethics, a more humane perspective, and cooperation-oriented [31].

3.1.2 Qualitative Methodologies

They rely on qualitative collection data and analysis, flexible semi-structured interviews, matrices, and tables to describe and contrast one or more specific characteristics in LFSC. In a research study [32], they propose a risk matrix that evaluates how company size and its links affect the performance, the traceability system consistency in storage conditions and packaging quality. Multi-criteria performance matrices can be used for decision making in distribution [33]. A mixed method is developed with data interviews qualitative and survey quantitative data analyzed in SC by combining contingency theory methodologies and resource-based theory [34]. In countries such as Vietnam, for short food chains development between farmers and distributors, semi-structured interviews have been used to achieve price stabilization, sustainability and decision-making in situations such as COVID-19, issues affecting smallholder farmers [35]. Likewise, expert stakeholders in fish SC have used information systems and technology for facilities and transport with cold requirements [36].

Impact and challenge tables are used to measure and characterize the technologies impact as internet of things, blockchain, big data and artificial intelligence, defining faster and cheaper delivery options in distribution centers and limited storage scalability [37]. The relationships with the FSC links can also be characterized by the PPT methodology (People-Process-Technology) where the blockchain ensures the measurement of food authenticity through traceability in storage, transport and distribution [38] and packing [39]. RFID radio frequency technology is used in distribution centers, packing processes and inventory levels with traceability for the recall of unsafe products in the reverse LFSC, using cause and effect analysis methodologies from current Food, Drug Administration and USDA regulations [40].

Content analysis is used through literature review to study sustainability in FSC and the importance of economic, social and environmental aspects in distribution and packing [41]. In a social approach, a FSC of artisan producers is observed using the methodology of content analysis, information gathered through interviews, documentary analysis and direct observation, in commercial spaces, meetings with suppliers, product dissemination, marketing and transport [42].

3.1.3 Multi-criteria decision-making (MCDM) methodologies

These methodologies help to have a more detailed characterization perspective with information generated mainly by experts. They allow observers and experts to understand issues of some complexity to make decisions from different perspectives. The Analytical Hierarchy Process (AHP) has been used to determine parameters that affect the FSCs sustainability where packaging and packing have a direct impact in terms of reuse and recycling [43] in energy consumption in industry structure and gas emission in the FSC [44]. The AHP methodology can be combined with Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to define storage, facility and transport risks caused by poor food handling, and thus be able to make good decisions on waste reduction [45], studying the efficiency of technology management in the FSC to ensure shelf life. TOPSIS together with the Elimination et Choix Traduisant la Realité (ELECTRE) methodology and the cross efficiency method (CE) serve to rank the countries with the most cereal exports to the US, identifying multi-criteria risks in socio-economic and institutional conditions in terms of food safety and transport [9].

The interpretive structural model (ISM) segments the information and develops organizational or hierarchical processes, and has also been used to analyses risks generated by 3PL in the coffee LSC, the success factors related to storage and transport, integrating expert information through the MICMAC and Fuzzy TOPSIS methodologies to priorities risks [46]. With regard to sustainability in perishable FSC in developing countries, the ISM methodology was used in conjunction with the analytical network process (ANP) to identify and model economic development, including infrastructure, adequate cold storage facilities and waste mitigation [47]. The ISM methodology is also used with the MICMAC cross-impact matrix to determine the causes of food loss in transport, inadequate packaging, poor storage facilities and lack of information exchange in the fruit SC [48], as well as to identify causes of post-harvest losses in 3PL transport [49].

For the elaboration of an integrated performance measurement framework and the interdependence of criteria including transport and storage, a hybrid method of Fuzzy with MCDM (multi-criteria decision making) is used [50]. Methodology based on the Fuzzy-DEMATEL (Fuzzy Decision Making) interpretative structural model together with the Fuzzy-DELPHI methodology, identify and analyze the elements of FSC and its risk dimensions in sustainable aspects, pollution produced in storage, transport and distribution [51]. Besides, the Best Worst Method (BWM) methodology is applied to evaluate alternatives for sustainable decision-making in a flour SC with inadequate storage systems that cause quality loss [52]. With methodologies such as MAUT (hybrid multi-criteria model between the multi-attribute approach) and PROMETHEE (preference ranking organization method for enrichment evaluation) determine the suppliers sustainable performance and propose improvements in FSC management [53].

3.1.4 Statistical methodologies

The information collected in statistical studies is based on activities such as interviews and structured questionnaires that allow capturing useful and necessary data for the respective statistics. Demographic statistics are used in the interest of understand the different actors integration impact in FSC, in cold chain context [54], for data recorded from demographic surveys, time series are also used to show behavioral patterns, in this case, of the impact of supply and transport on the pandemic [12] or, with regression, to assess risk elements with their probabilities and consequences on LFSC and infrastructure [55]. Structural equation modelling is also used to estimate causal relationships between variables, whit regard to understand raspberry chain fragility affecting safety in the storage, distribution and packaging processes [56,57] applies it in a sustainable management with traceability context.

In some cases, several methodologies are used to improve results. Thus, structural equations interact with other methodologies such as exploratory factor analysis, allowing for greater precision in the experts' observations. In sustainable environments and associations involved in distribution [58] or, distinguishing factors affecting these interorganizational relationships in a vertical coordination [59]. Structural equations with resource-based theory allow exploring the impact of traceability on food packaging [60].

Other statistical techniques used for the characterization and processing of FSC data are logistic regressions. Thus, statistical techniques focused on a literature review as topic mapping, co-citation and co-authorship were proposed in order to address issues related to sustainability and new technological challenges [61]. On the other hand, there are methodologies that perform monitoring with statistical control processes (SPC) and allow distinguishing variations that may alter the FSC, being applied in the diagnosis of the economic impact of inadequate management of the cold chain in supply and storage [62].

3.2 *Evaluation methodologies*

The literature includes mathematical modelling, machine learning, simulation, system dynamics, quantitative methodologies and other methodologies, shown in Table 3.

Table 3 Logistical modes and means in Evaluation methodologies

		Mathematical Modeling	Machine Learning	Discrete Simulation	Dynamic Systems	Quantitative	Other
MODES	Storage	2	2	1	1	1	0
	Supply	0	0	0	0	1	0
	Distribution	1	2	2	2	2	2
	Packaging	0	0	0	0	2	2
	Inventories	1	1	1	1	2	1
MEANS	Transport	3	2	3	1	4	2
	Packing	0	1	0	0	0	1
	Facilities	1	2	1	1	1	0

3.2.1 Mathematical modeling methodologies

Lineal programming models evaluate different environments; in [63] they develop a multi-objective VRP model for last-mile perishable fruits, in order to reduce organoleptic properties loss caused by congestion in megacities. On the other hand, the use of fuzzy integral assessment was found to evaluate the risk of food quality for the consumer, due to contamination in storage and transportation, so it is necessary to consider different controls on temperature, inventories and technologies. [64]. Likewise, data envelopment analysis (DEA) used to evaluate performance of genetically altered foods with respect to transportation fuel costs [65,66] evaluates tradeoffs in Biodiesel chain design by means of a multi-objective optimization model. Game theory is also applied at the environmental level in decentralized or nondecentralized decisions between a cooperative company and consumers, considering transportation, optimal order quantities and environmentally sustainable processing [67]. Mathematical optimization is used to assess both economic and environmental feasibility with respect to waste and costs incurred, for example, in logistics facilities [68].

3.2.2 Machine learning methodologies

They are used to evaluate a large amount of information and obtain optimal results more efficiently, quickly and with greater precision. In turn, [69] evaluate the sustainable LFSC of grapes, propose a system of risk assessment indices through the methodologies of an optimized BP neural network (back propagation neural network, GABP and PSO-BP). In this case [70] applied a simulation and numerical analysis methodology to evaluate the incurred risks in strawberry cold chain, analyze factors affecting quality and food safety in fresh produce, including technological, biological, environmental and emergency risks in storage, facility management, distribution, and transportation.

3.2.3 Discrete simulation methodologies

This group includes articles that have used discrete simulation, such as that developed by [27] which evaluates transportation costs between different modes, shrinkage reductions and temperature control in food distribution using an ALADIN (Agro-Logistics Analysis and Design Instrument) simulation environment specialized in the food industry, while [71] studies factors that influence the horizontal collaboration of a horticultural SC, with transportation being the most important. Another aspect is the use of technologies, in [72] present the CAS (complex adaptive system) to evaluate food safety in a FSC, and it allows to understand the problems in the distribution with the RFID use.

3.2.4 Dynamic systems methodologies

These methodologies are used to analyze dynamic environments, in the paper [73] evaluate the capacity of future vehicle routes for the potato SC, in [74] the effects of multimodality are evaluated on the perishable FSC logistic performance, on the other hand in [75] evaluate the design of the perishable FSC in food safety and logistics, and finally on [5] evaluates the impact of traceability on bullwhip effect.

3.2.5 Quantitative methodologies

The most widely used is product life cycle assessment (LCA). In [76], authors evaluate the material costs that affect the FSC of perishable goods in order to achieve sustainability. In [77] a SC of biscuits is studied using LCA to address issues such as environmentally sustainable packaging and transport to reduce emissions and distances. Regarding the evaluation of sustainability processes in global and short CSA, in [78] they use LCA to evaluate inventories, transport, storage and distribution. In the case of [79] they study perishable foods such as tomatoes and consider transport and packaging for the quality of the final product. The research carried out in [80] evaluates transport and supply by means of an ecological last-mile transfer system with hand carts and bicycles, quantifying demand, supply, and market situations, by means of a feasibility study.

3.2.6 Other methodologies

The DEMATEL Methodology is used in decision-making processes by analysing interdependence between different components, and in the case of FUZZY-DEMATEL it allows to build and evaluate interrelated structural models with cause and effect by identifying sustainability drivers such as transportation, using the supply network to meet customer requirements [81]. For processes in the agricultural FSC related to sustainability, [82] uses the Fuzzy-DEMATEL and model a multilevel system, managed with different emerging technologies application, internet of things in a COVID-19 environment, and evaluating the intelligent packing of agricultural products.

TOPSIS in a fuzzy environment and together with set theory are used to define which information systems to use in LFSC and to assess compliance with traceability requirements in current legislations [83]. For expert-based models [84] combine DELPHI and mode-effect analysis to evaluate the impact of change drivers such as food security packaging vulnerability in an aquaculture chain.

In another paper, Chan and Qi have studied the feasibility of SCPMS based on process-based metrics. They have considered five processes (supplying, inbound logistics, core manufacturing, outbound logistics, and marketing and sales) [85].

3.3 Improvement methodologies

These methodologies represent systems with different models to develop improvements in aspects such as the use of technologies, cost reduction or vulnerability in FSC, among others. They were classified into means and modes vs. mathematical modelling, system dynamics, simulation and other methodologies, Table 4.

3.3.1 Mathematical modeling methodologies

The mathematical modelling found presents different improvement strategies in FSC. In [86] studies supply, transportation and distribution, optimizing logistics costs and quality associated with storage and refrigeration in environments of uncertainty and variability. Faced with situations in volatile and changing environments, [87] studies the resource utilization vulnerability, costs and operational risk through the traceability model with a quality and food safety perspective. With mathematical modelling, [88] analyses the RFID impact with a newspaper vendor model and the benefit of reducing inventory losses in a FSC. [89] evaluates RFID technology with QR, GPS and Blockchain used in traceability, for quality and cost improvements, through contract coordination policies, is applied to fresh chicken FSC. On the other hand [90] contextualizes FSC with the objective of improving farmers' incomes through product quality, storage and transportation.

Improving the perishable FSC network with transportation and distribution centers for better performance is being studied by [91], where evaluation uses a mixed integer linear programming model. In [92] proposed a sustainability model that lowers the costs of implementing rail-road intermodal transportation for perishable foods and reduces carbon footprint.

On the other hand, [93] proposes a multi-objective IRP model (inventory-routing-problem) for improving distribution performance in a FSC. In [94] a multi-objective, multi-scale, multi-product model developed from mixed integer linear programming proposed to improve a perishable FSC with seasonality in a developing country in order to design the logistics network, contemplating packaging, transportation and storage and allowing the actors to approach the efficiency frontiers. [95] proposes a LIRP (Location-inventory-routing problem) model with mixed integer linear programming, decreasing distribution costs in small farmers for fresh FSC, is solved with genetic algorithms and Lagrangian relaxation. Meanwhile, [7] proposes a multi-objective optimization model for FSC network design to improve food availability and access.

Table 4 Logistical modes and means in Improvement methodologies

		Mathematical Modeling	Discrete Simulation	Dynamic Systems	Other
MODES	Storage	3	1	1	0
	Supply	2	0	0	0
	Distribution	6	2	1	1
	Packaging	1	0	1	0
	Inventories	4	1	2	0
MEANS	Transport	7	2	2	2
	Facilities	1	1	0	2

3.3.2 Discrete simulation methodologies

In [96] a graphic interface is developed to reduce delivery times in the agro-industrial sector to reduce costs and increase efficiency. Through simulation, it shows a decrease in fuel, maintenance, and tire costs during processes such as transportation and distribution. In [97] they propose business models with the use of technologies, interconnected electronic networks of grocery stores looking for sustainability, minimize food waste through inventory management and distribution, the simulation showed better results in an internet of things environment. Based on the application of value chain mapping supported in food losses reduction in FSC [98], a model with different simulation scenarios is made to improve sustainable processes in logistics, storage, transportation and facilities.

3.3.3 Dynamic systems methodologies

A model that allows product quality characteristics to be preserved is presented by, through system dynamics is improved by reducing food waste in excessive inventories and inadequate quality, to maximize retailer profits through pricing, based on the shelf life of food. The paper [99] evaluates external integration mechanisms for the improvement of fruit FSC, in [100] is evaluates better packaging management in transportation and storage in fruit FSC. On the other hand, [101] analyses different structures for perishable FSC design with the dynamic system paradigm, taking into account inventories and transportation to obtain better logistic performance. In [102] evaluates traceability systems for better performance of FSC.

3.3.4 Other methomologies

Using Fuzzy-DEMATEL and Fuzzy-AHP techniques, in [3] they evaluate the improvement of food quality in cold transport and the search for suitable 3PL and facilities, and identify criteria to reduce losses in SC of fruits and vegetables. [13] employs ISM and DEMATEL technologies, developing an efficient system based on internet of things that improves the coordination mechanism, to optimizes and automates the agricultural infrastructure. [103] explores the possible strategies in perishable FSC to improve their resilience, using Best-Worst Method (BWM), correlate them with Quality Function Deployment (QFD), to maintain the flow in distribution and transportation from farmer to consumer in an uncertain trading environment during COVID-19.

3.4 Performance measures

There are several performance measures found in the literature. In [29] authors identify flexibility, responsiveness, efficiency, quality, effectiveness, efficacy and profitability for LFSC. These measures are used in the LFSC performance evaluation of all parties involved, their interdependence is analyzed by [50] , while in [32] they study how the size of the company impact sustainable performance, on the other hand [58] pose measurement models that evaluate partnerships in FSC and [39] evaluates the blockchain in FSC performance.

Flexibility in FSC is related to several aspects such as the links or agents ability to make decisions under an uncertainty environment [31] , the use of technologies such as ERP in planning and risk analysis for decision making [24]. As for responsiveness in LFSC, it is measured with respect to sustainable packaging and packing, storage, distribution and transportation [64],and horizontal collaboration of producers by sharing information in order to meet demand [71]. In the article [63] FSC design is evaluated and its impact on the preservation of organoleptic properties and reduction of losses, improving food availability and access.

The efficiency of FSC is mainly related to economic aspects, which is reduced due to losses [94], improved through the control and assurance of the cold chain [56] and the adequate temperature management in transportation [92] or logistic processes [98]. Also through the use of EDI (information exchange) in the FSC [104]. For its part, Profitability is related to the economic performance that allows the growth of the FSC, in which case costs [105] and recently the environmental impact [89] or operational risks [87], or associated with food safety [106] are considered. While effectiveness in LFSC is related to the business environment, in the achievement of goals or objectives [21].

Perhaps quality is the most used performance measure in the LFSC, where in [107] they study the risks in safety and uncertainty [67], including according to ingredients quality or green agroecological products and [57] environmental, while [101] studies the food safety, in [36] the sustainability or the impact of technologies in traceability. Sophisticated techniques of temperature controls in the cold chain are also found in[62], presenting in [84] the vulnerabilities of the change in the performance of salmon FSC. In paper [25], quality related to social and [90] business integration factors. Figure 3 show the use of performance measures depending on each type of methodology, being characterization, evaluation, and improvement.

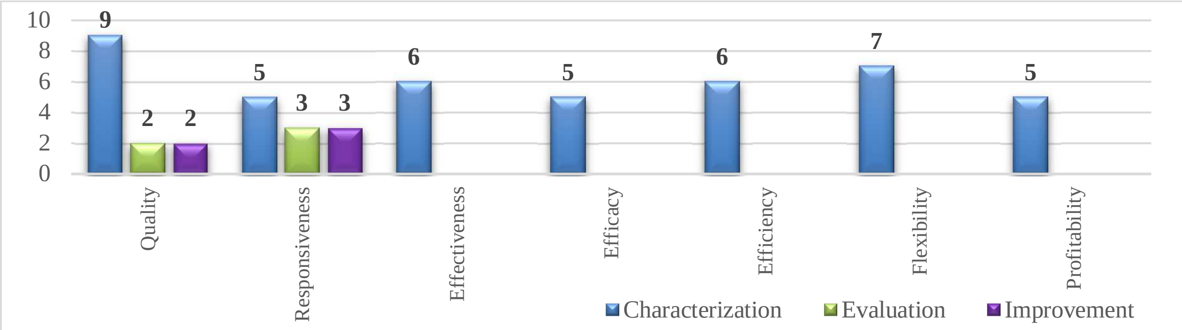

Figure 3 Performance measures vs. Characterization, Evaluation, and Improvement methodologies

4 Discussion, challenges and trends

FSC faces several challenges regarding environmental, social and economic sustainability, in accordance with the Strategic Framework for 2022-2031 [108]. The responsible use of resources, proper solid waste management, environmentally friendly, recyclable and reusable packing [52], and logistic means that avoid losses, the use of means of transportation that avoid increasing the carbon footprint, with the use of appropriate technologies and strategies for transportation (land, air or sea) and storage, contribute to risk mitigation [23], to the durability of food in the market and the environment, especially with temperature control and other preservation technologies, using technologies that maintain the product life cycle, with cooling and preservation processes, so that the food reaches the final consumer in safe and quality conditions. Food safety must be guaranteed. Food produced organically, without preservatives or additives, is becoming increasingly important.

LFSC has different challenges to face; during the life cycle, logistics processes influence the physical-chemical, organoleptic and biological characteristics and alter the conditions in which food reaches the consumer [77], which affects the performance of the FSC. [54] and [109] lead companies to hire 3PL logistics operators and use specialized logistics platforms [110]. Businesses must make decisions that help LFSC compliance and generate a positive impact [111] and a proper FSC management [112].

Organizations should carry out horizontal logistics practices that allow collaboration, information flows and address problems such as variability and risks present in FSC [71]. In the FSC, the links must be integrated [99] through co-regulation, coordination [113], government policies in favor of contributing to food safety [114], in compliance with norms, standards and logistic customs of the countries [115,116]. With respect to economic, social, environmental and governmental aspects, a balance is sought between demand, supply and food flows and associated information in logistics processes [1], as well as the search for sustainable objectives at strategic, tactical and operational levels [37].

Use of technologies that facilitate interoperability for decision-making by chain actors in real time [88], better quality conditions are achieved, generating controlled environments that contribute to food safety, risk mitigation and information control with traceability systems in the SC

[117]. The use of new technologies in the information era, make LFSC to modify and adapt according to the dynamics of the environment [95]. The evolution of technology that brings with it paradigms [118] that in conjunction with the logistics 4.0 concept [34,119], allows better traceability [120]. The storage with cold chains and using RFID (radio frequency identification system), WSN (Wireless sensor Networks or sensor network), EPC (electronic product code) and integrated blockchain; which allow the updating in real time information and improve responsiveness in LFSC [120-122], for large number of data [97,123].

In the above context, the characterization of LFSC requires the use of methodologies that allow establishing their heterogeneity and particularity, specifically of perishable products with different life cycles, short chains, in changing environments. The evaluation of performance requires a combination of modeling techniques to reflect the dynamics of LFSC and proposals for improving scenario evaluation strategies that represent reality, uncertainty, and risks in vulnerable environments such as pandemics.

Developing countries have many small producers in the first mile and traders in the last mile, generating modeling challenges for the design of the FSC network and its logistics. Considering the efficiencies of territorial proximity and the integration of the different links of the FSC, logistics clusters and productive chains. Transportation in the FSC in a fast and efficient way, with delivery routes so that it arrives correctly and in the established times, from the first to the last mile. For this purpose, advanced multi-objective and multi-link mathematical optimization and simulation models that approach the behavior of reality and include dynamics, uncertainty, risks, resilience, require new solution methods. And finally, the use of new strategies such as multimodal transportation, technologies application as RFID, Blockchain, Internet of Things, environment simulation processes and even methods application as Machine Learning that seek sustainability.

5 Conclusions

In this systematic literature review, different characterization, evaluation, and improvement methodologies in logistics in food supply chains (LFSC) were found. Through the evaluation of 123 articles, obtained from Web of Science, Scopus, and Google Scholar, proposed a taxonomy to management methodologies, qualitative, quantitative, MCDM, statistics, machine learning, mathematical modeling, simulation, and system dynamics, also grouped in logistics means and modes.

The need to include sustainable performance measures, in economic, environmental, and social aspects, complemented with logistics measures are identified as trends. Methodologies should allow to assess application level of modern technologies as traceability systems, internet of things, blockchain, logistics 4.0. The evaluation models and improvement proposals are of diverse types: optimization, simulation, management system dynamics, multi-criteria, analytical, qualitative, quantitative, or statistical. The challenges of these evaluation methodologies are to include elements that are closer to a changing reality, with uncertainty and risks, and it is necessary to develop multiobjective multilevel, multi-link and/or stochastic models. These methodologies should contemplate specific aspects of LFSC, such as varied life cycles, perishability, losses, organoleptic and physicochemical characteristics of food, cold chain, control, and monitoring of quality in real time.

Gaps between first and third world countries hinder research applications due to deficiencies in land routes and distribution networks, transport methods, problems of corruption and lack of government policies, investments for the improvement of perishable FSC, waste, excessive costs, and losses in the flow of food.

Despite the substantial differences found between the different food chains, this article provides an overview that potentially serves as a basis for researchers in future work on methodologies to characterize, evaluate or improve LFSC.

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