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Exploring Performance Evaluation Methodologies in Agri-food Supply Chains

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ABSTRACT

This study aims to systematically review the attributes of Agri-food Supply Chain Performance Evaluation Methodologies (ASCPEMs). To accomplish this, we employed a systematic literature review methodology, focusing on peer-reviewed journal articles published between 2007 and June 2023. By examining 123 papers, we observed a growing number of publications on ASCPEMs. A similarity analysis enabled the identification of common characteristics among the methods studied, including the agrifood supply chain processes analyzed, evaluation objectives, aspects assessed, application cases, analysis methods, information sources, and data collection techniques. These characteristics outline prevailing trends in food supply performance. The findings elaborate on these trends for each characteristic, supported by reference examples. This review, the first of its kind to characterize ASCPEMs, also identifies future research directions and emerging gaps in information management technology. Among the findings, it was noted that information and Industry 4.0 technologies are sparingly utilized, and data collection methods are predominantly manual, resulting in delays in performance analysis.

Keywords: *agri-food supply chain, performance evaluation, systematic literature review*

1. INTRODUCTION

The Agrifood Supply Chain (ASC) encompasses various interconnected components within the agribusiness sector, including production systems, suppliers, processing industries, logistics agents, and final consumers (Flórez M., 2017). Materials flowing through the ASC primarily consist of biological organisms prone to degradation, which, as noted by Keizer *et al*. (2017), adversely affects quality and contributes to food waste and losses. Consequently, specific methods and technologies are necessary to mitigate these known risks (Berkowitz, 2012; Navia *et al*., 2010).

According to Guo *et al*. (2020) and Raut *et al*. (2019), approximately 34% of global food production is wasted (12%) or lost (22%). The latter portion is distributed across various stages of the supply chain: production (13.77%), post-harvest (6.73%), and industrial processing (1.19%). To mitigate the negative impacts of food wastage and loss on food security, final consumer price variation, and farmers' income; current trends are heading towards ASC performance evaluation (Kazancoglu *et al*., 2021). However, in line with Devkota *et al*. (2020), such evaluation is a complex task, since this supply chain involves the interaction of environmental, social, and economic aspects. In most cases, except for climatic factors, the causes of ASC losses are linked to the lack of a comprehensive Performance Evaluation (PE) of the system as an integrated whole (Dania *et al*., 2018; La Gra *et al*., 2016; Shukla *et al*., 2018; Vodenicharova, 2020).

PE within a supply chain entails addressing the question of "how the various components of the chain are functioning concerning established objectives and predefined performance standards" (Kogachi *et al*., 2021). To achieve this, several aspects of the supply chain are meticulously examined, including operational efficiency, service quality, customer satisfaction, risk management, and profitability (Kruger *et al*., 2022).

In practical terms, Ali *et al*. (2024), Wei *et al*. (2022), and León *et al*. (2021) propose that PE within an ASC facilitates achieving five primary outcomes. Firstly, Food Security stands out as an absolute priority in ASC operations, where the PE allows for monitoring and ensuring compliance with food security standards at every stage, from production to final consumption. Secondly, Product Quality is paramount for maintaining customer satisfaction and safeguarding brand reputation, focusing on meeting expected quality standards such as freshness, flavor, texture, and appearance. Thirdly, Production Efficiency involves monitoring resource utilization—such as land, water, energy, and labor—to enhance productivity and reduce production costs. Fourthly, Cold Chain Management is crucial for many perishable foods, requiring precise temperature and humidity conditions during storage and transportation. Lastly, Sustainability emerges as a key concern for consumers interested in the environmental, social, and economic impacts of the products they consume. In this regard, PE facilitates the monitoring and improvement of sustainability across agricultural production, packaging, transportation, and waste management processes.

However, PE within an ASC presents additional complexities due to inherent industry characteristics such as perishability, climate dependence, a variety of suppliers, and specific regulations (Yontar and Ersöz, 2021). The ASC deals with a diverse range of perishable products that require efficient management of the cold chain and distribution logistics to ensure consumer freshness and quality (Afshar *et al*., 2022). On the other hand, the ASC heavily relies on climatic and seasonal factors, resulting in fluctuations in supply and demand, and sometimes necessitating an assessment of responsiveness and resilience to natural risks. This calls for greater flexibility in supply chain planning and management to adapt to abrupt changes (Afshar *et al*., 2022). Additionally, the ASC manages a diverse range of suppliers and producers, frequently operating on a small scale, which presents a heightened challenge in coordinating supply and establishing performance benchmarks (Elyasi and Teimoury, 2023). Finally, the ASC must ensure compliance with specific regulations and standards concerning food safety, labeling, traceability, and agricultural practices, which requires ensuring full compliance with these regulations (Antohi *et al*., 2019; Attrey, 2017; Mayett-Moreno and Oglesby, 2018).

Now, recognizing both the benefits and complexities associated with PE in an ASC, the question arises: how do stakeholders within an ASC select the PE methodology that best suits their operational conditions while also considering scientific and business trends?

Following an initial exploratory analysis conducted by the authors to refine the research focus and identify more accurate keywords, it was found that there is a marked paucity of studies that consolidate the principal characteristics of Agri-food Supply Chain Performance Evaluation Methodologies (ASCPEMs). Therefore, this study aims to systematically review and synthesize the characteristics of ASCPEMs reported in scientific literature.

To accomplish this goal, the paper is structured as follows: Section 2 outlines the methodology employed for the systematic literature review; Section 3 provides a detailed analysis of the results obtained from examining each of the identified ASCPEMs characteristics; finally, Section 4 concludes with findings based on the research question and suggests potential avenues for future research.

2. RESEARCH METHODOLOGY

The current methodology is based on Arksey and O'Malley's methodological framework, introduced in 2005. This approach was later contextualized by Levac *et al*. (2010). The process consists of five steps: identifying the research question, ascertaining relevant studies, selecting those to be included, charting and collating the data, and summarizing and reporting the results.

2.1 Identifying the Research Question

According to Levac *et al*. (2010), the research question provides the roadmap for the following stages and should, therefore, be broad enough to do so. Hence, and with a focus on ASC, Lehyani *et al*. (2021) have noted that due to the growing complexity of supply chains, PE perspectives vary widely, leading to a plethora of methodologies. To address the earlier question of how a stakeholder can select a PE methodology among many alternatives, this research aims to streamline this decision-making process by characterizing methodologies documented in scientific literature. The characterization is based on a set of research questions formulated through discussions among the authors and a thorough review of academic and industry studies, aligning with Kafa and Jaegler (2021).

Based on this process, this review aims to tackle the questions outlined in Table 1. For enhanced clarity, a conceptual description of the characteristic corresponding to each question is provided within the same table.

2.2 Ascertaining Relevant Studies

In order to recognize relevant studies, a PRISMA (Preferred Reporting Items for Systematic and Meta-Analyses) scoping process flowchart (Peters *et al*., 2015) was followed, as shown in Figure 1.

The literature search was initially performed with the following equation: ("performance assessing methodolog*" OR "performance methodolog*" OR "performance assessment methodolog*" OR "performance evaluation") AND (agri-food OR "agri-system" OR "agri system" OR food OR "food security" OR "food safety") AND ("supply chain*" OR "supply chain management"). The search

Table 1 Identified ASCPEMs Characteristic

No.	Characteristic or research question	Description
1	Which ASC processes are involved in ASCPEMs?	The ASC processes are the operative stages covered by the scope of the methodology.
2	What is the goal of PE using ASCPEMs?	It is the performance evaluation goal.
3	What is evaluated by ASCPEMs?	Refers to the process, context, system, or medium through which performance is evaluated.
4	What cases have ASCPEMs been applied to?	The cases refer to the specific agricultural contexts in which the methodologies in question are applied or validated.
5	What are the analysis methods applied by ASCPEMs?	The analysis method involves processing the collected information to obtain a desired output.
6	What are the information sources employed by ASCPEMs?	The information source is the origin of the input data processed by the methodology.
7	What are the data collection techniques employed by ASCPEMs?	The collection technique refers to the material or digital mechanism used to collect raw data.

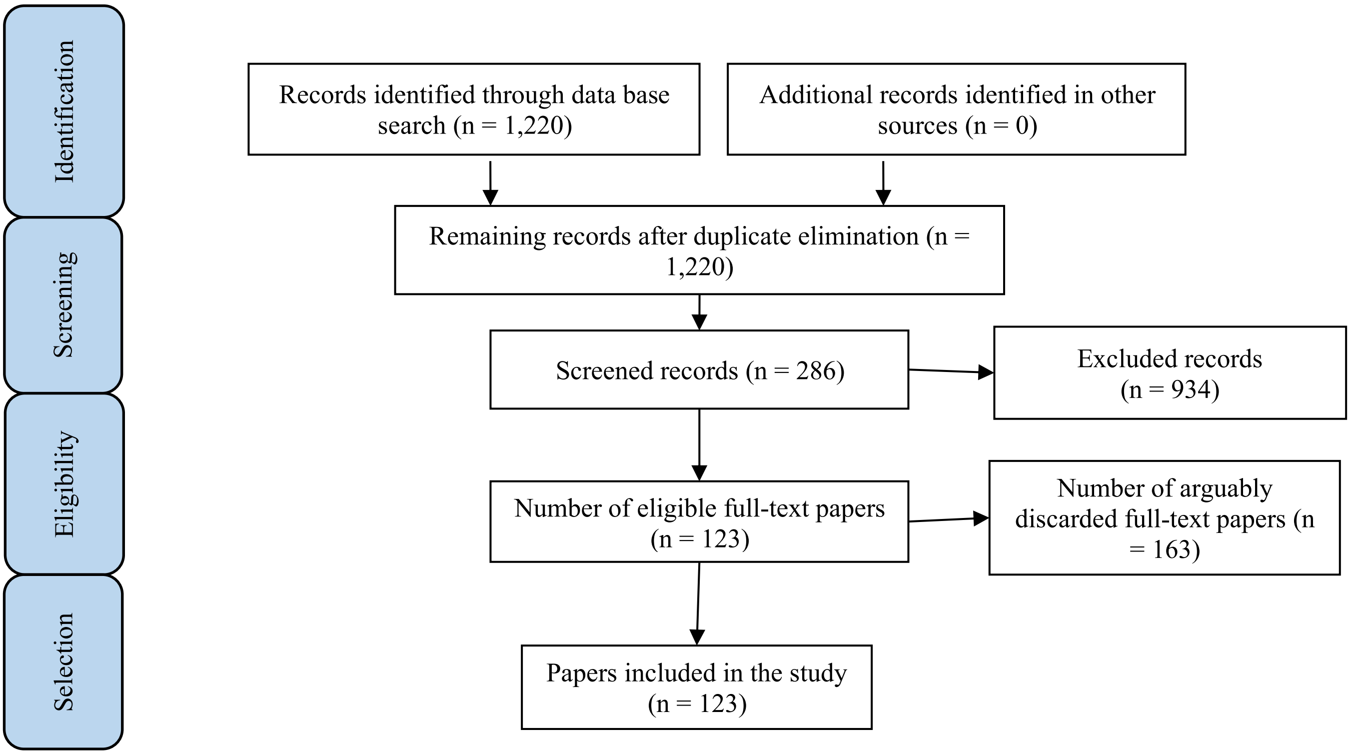

Figure 1 PRISMA Flow Diagram for the Scoping Review Process. Source: Peters *et al.* (2015)

equation was typed into the title, abstract, and keyword fields of the SCOPUS database. Other criteria considered in the SCOPUS database were the type of document (article or review) and language (English or Spanish). A total of 1,220 records were identified at this phase.

The second step consisted of a screening process through which the publications retrieved in the previous stage were refined by applying the following criteria:

1. Publications whose title and abstract demonstrated alignment with the research topic were included, specifically those addressing the design, evaluation, validation, or analysis of any ASCPEMs model.
2. Only peer-reviewed articles published in indexed scientific journals were considered to ensure academic rigor and methodological reliability.
3. Publications addressing food-related issues that were not focused on supply chain performance evaluation were excluded.
4. Publications for which full-text access was not available were excluded from the review.
5. No temporal restrictions were imposed, as the aim was to capture the evolution of the research field over time.

The papers were recorded and selected in Microsoft Excel 365. By applying the described screening procedure, 286 articles were obtained for full-text evaluation.

2.3 Study Selection

The third step corresponded to the eligibility phase. After evaluating the full text of the 286 papers, 123 were identified as eligible for inclusion. In this phase, the inclusion criterion applied was that the study must clearly describe the characteristics outlined in Table 1 for the ASCPEMs under analysis. Specifically, it should specify the procedures for data collection, processing, and analysis, as well as state the purpose of the study, the agricultural product under consideration, and the agri-food supply chain (ASC) processes involved.

There was no need to apply post hoc inclusion or exclusion criteria, as the previous selection of publications had been sufficiently exhaustive.

2.4 Charting the Data

In reviewing the full text of each article, the corresponding observations were recorded in a spreadsheet, according to the characteristics detailed in Table 1.

2.5 Collating, Summarizing, and Reporting Results

The identified ASCPEMs' features were analyzed according to their frequency of appearance in the studied documents to present an overall perspective of these methodologies.

3. RESULTS

Initially, a descriptive analysis of the 123 documents was conducted. Between 2007 and 2021, the number of publications dealing with ASCPEMs continued to increase (Figure 2), followed by a slight decline in 2022. The last 5 years were observed to group 54% of the literature (66 papers).

The 123 articles were published in 78 different journals. Table 2 shows the top ten journals, which collectively account for 40% of the publications. Among them, "Sustainability" is the predominant one (16%), followed by the "Journal of Cleaner Production" (6.5%) and the "British Food Journal" (3.2%).

The following sections present the main findings corresponding to this stage of the analysis, as outlined in

Table 2 Top Ten Academic Journals Ranked by Number of Publications

Ranking	Academic Journal	Papers
1	Sustainability (Switzerland)	20
2	Journal of Cleaner Production	8
3	British Food Journal	4
4	IOP Conference Series: Earth and Environmental Science	3
4	Agriculture (Switzerland)	3
4	Ecological Indicators	3
5	Journal of Environmental Management	2
5	Journal of Industrial Ecology	2
5	Sustainable Production and Consumption	2
5	Food Control	2

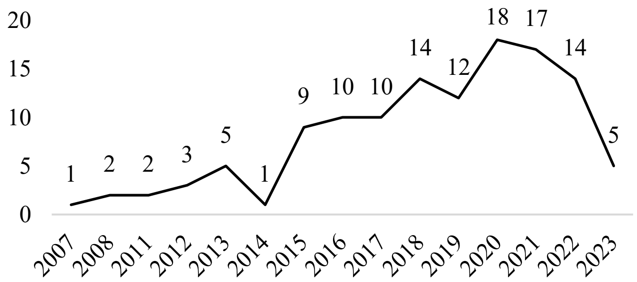

Figure 2 Summary of relevant ASCPEMs articles by year

Table 1. The description begins with ASC process coverage and continues with PE purposes and Evaluated factors. These items are followed by Application cases, Analysis methods, and, finally, information sources and collection techniques.

3.1 Which Processes are Involved?

The ASC process categories addressed by the various ASCPEMs types studied are depicted in Figure 3. Most of the literature (59%) applies the methodology to assess the performance of all ASC processes. This corresponds to the "All" category, which, based on the 73 papers included, encompasses a range of activities, including procurement, production, processing, storage, post-harvest handling, transportation, retail, distribution, and marketing.

Following the "All" category is "Production," representing 14% of the literature, which not only evaluates production activities but also encompasses land management and resource utilization during crop growth and development (Thongmai *et al*., 2021). The third category is "Retail" (11%), where research efforts aim to inform decision-making related to marketing and final consumer sales (Raut *et al*., 2019). Studies evaluating the "Global ASC" (2%) cover all its processes, along with importation or exportation activities involving raw materials, semi-processed, or finished products (Karipidis *et al*., 2020). The "Land Transport" category (2%) typically involves transportation from production to storage or from storage to retailers. "Processing" (2%) pertains to value addition to primary products through physical or chemical transformation techniques (Kogachi *et al*., 2021). "Post-harvest" (2%) focuses on processes leading to product readiness and suitability based on market requirements, from harvest to vehicle loading (La Scalia *et al*., 2017). "Procurement" (2%) addresses the purchasing function within organizations, including supplier analysis (Alfazah *et al*., 2020). Finally, the "Others" category encompasses consumption, catering, packaging, storage, and international sea shipping.

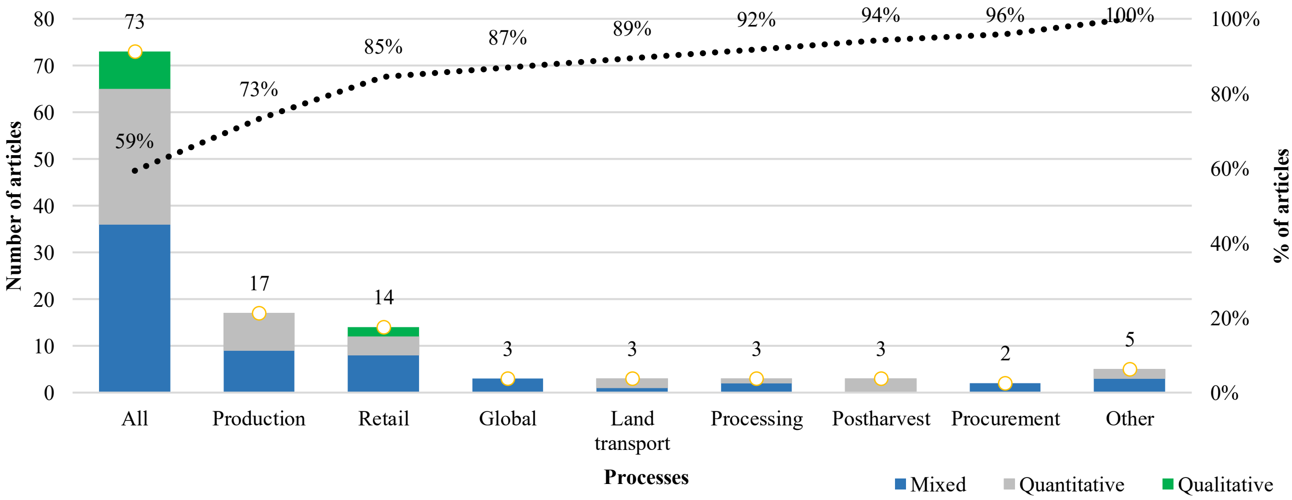

Figure 3 ASC processes included in ASCPEMs

Figure 4 Pareto of ASC processes by application case category

In addition, Figure 3 categorizes ASCPEMs based on the types of procedures they entail, distinguishing between quantitative, qualitative, or mixed methodologies. Mixed methods represent 52% of the literature reviewed, primarily applied across the integrated spectrum of all ASC processes and sometimes focusing solely on production and retail. According to Elyasi and Teimoury (2023) ASC contexts encompass both tangible and intangible elements, necessitating a comprehensive understanding that can be achieved through the simultaneous application of quantitative and qualitative methods.

Quantitative methodologies (40%) are predominantly utilized across all ASC processes, particularly in production and retail, where they employ economic or productivity analysis indicators (Trigo *et al.*, 2023). Conversely, qualitative methodologies (8%) are commonly employed to evaluate all ASC processes, although in some instances, they concentrate solely on retail activities. Given their nature, these techniques typically address intangible elements such as stakeholder perceptions or the dynamics of social variables (Suhaeni *et al.*, 2021).

Figure 4 illustrates the distribution of papers depicted in Figure 3 across the application case subcategories outlined in Table 3. Notably, production analysis is prevalent in the production of beverages, seeds, and dairy products, while retail analysis is primarily applied to fruits, vegetables, and other food categories. As mentioned earlier, there is a consistent tendency to encompass all ASC processes.

3.2 What is the Goal of PE using ASCPEMs?

The purpose of an ASCPEM is to define its specific evaluation goal. According to Figure 5, research on this topic has pursued 11 different purposes, with the most frequent being Sustainability (39% of the literature), which integrates economic, environmental, and social aspects. For instance, Pérez-Mesa *et al.* (2019) analyzed the ability of small-scale fruit and vegetable farmers to respond adequately to retailers regarding specific aspects of sustainable planning in ASCs.

Continuing with the sustainability goal, Figure 5 indicates that 16% of the papers studied address sustainability axes independently. Among these, the environmental axis is the most addressed, followed by the social and economic aspects. Food systems often aim to align with Sustainable Development Goals to meet environmental sustainability objectives (Ma *et al.*, 2019). Social and economic sustainability have also been explored, with studies focusing on integrating public concerns into overall ASC performance (Grivins *et al.*, 2016) and examining the impact of chain operations on financial metrics and resource allocation (Gambelli *et al.*, 2021).

Furthermore, as shown in Figure 5, the second most common goal of ASCPEMs is Food Security, which has evolved. In essence, it refers to ensuring that everyone has consistent access to sufficient, safe, and nutritious food that meets their daily energy requirements and dietary preferences, thereby supporting an active and healthy lifestyle (Manikas *et al.*, 2022).

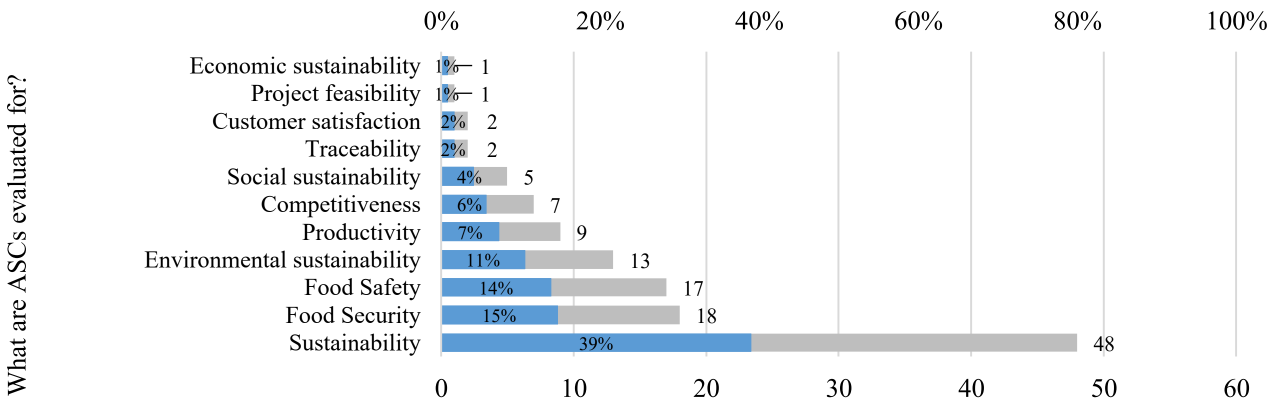

Figure 5 ASC performance evaluation goals

Table 3 Examples of Literature by Subcategory of Application Cases

Category	Subcategory	What is evaluated? *	Purpose	ASC Processes	Location	Methodological approach	Reference
28 Not applicable	-	Information system	Social sustainability	All	Not reported	Mixed	(Farooq *et al*., 2016)
24 Various Foods	22 fruits, vegetables, and processed products	Collaboration	Sustainability	Global	Greece	Mixed	(Karipidis *et al*., 2020)
	1 beef and dairy	Methodology feasibility	Economic sustainability	Production	EU	Mixed	(Gambelli *et al*., 2021)
	1 meat, dairy, and catering	Risk management	Food safety	Procurement	Poland	Mixed	(Trafiałek *et al*., 2017)
18 Fruits and Vegetables	9 various fruits and vegetables	Practices	Sustainability	All	Italy	Qualitative	(León *et al*., 2021)
	2 strawberries	FLW	Food safety	Post-harvest	Italy	Quantitative	(La Scalia *et al*., 2017)
	1 fig	FLW	Food Security	Post-harvest	Turkey	Quantitative	(Ertan *et al*., 2019)
	1 food surplus	FLW	Food Security	Retail	Italy	Quantitative	(Damiani *et al*., 2021)
	1 lettuce	FLW	Sustainability	All	Spain	Mixed	(Bogataj *et al*., 2017)
	1 tomato	FLW	Productivity	Post-harvest	Africa	Quantitative	(Venus *et al*., 2013)
	1 table grapes	Methodology feasibility	Sustainability	Processing	Brazil	Quantitative	(Kogachi *et al*., 2021)
	1 berry	Collaboration	Social sustainability	All	Serbia	Mixed	(Grivins *et al*., 2016)
	1 banana	FLW	Sustainability	Processing	Australia	Mixed	(White *et al*., 2011)
13 Seeds	6 corns	Program compliance	Sustainability	Production	China	Quantitative	(Liang *et al*., 2018)
	5 rice	Operational efficiency	Sustainability	Production	India	Mixed	(Devkota *et al*., 2020)
	1 green bean	Practices	Food safety	Production	Kenya	Mixed	(Nanyunja *et al*., 2015)
	1 cashew	Collaboration	Sustainability	Production	Brazil	Quantitative	(Azevedo *et al*., 2018)
11 Beef, Pork, or Poultry Meat	4 poultry industry	Methodology feasibility	Sustainability	All	UK	Qualitative	(Tsolakis *et al*., 2018)
	4 pork	Methodology feasibility	Sustainability	All	France	Quantitative	(Petit *et al*., 2018)
	3 beef	SCM	Food Security	All	China	Mixed	(Zheng *et al*., 2021)
8 Processed	1 passion fruit syrup	Methodology feasibility	Competitiveness	All	Sumatra	Quantitative	(Kodrat *et al*., 2020)
	1 sausage	Information system	Food safety	Production	Italy	Quantitative	(Dabbene and Gay, 2011)
	1 pizza	Operational efficiency	Sustainability	Retail	USA	Mixed	(Duman *et al*., 2017)
	1 palm oil	Value chain	Sustainability	Production	Indonesia	Mixed	(Marimin, 2018)
	1 olive oil	Value chain	Sustainability	All	France	Mixed	(Fagioli *et al*., 2017)
	1 rapeseed	Practices	Environmental	All	Iran	Quantitative	(Mousavi-Avval *et al*., 2017)
	1 wood	Environmental impacts	Environmental	All	Pakistan	Mixed	(Ali *et al*., 2024)
	1 bread	SCM	Environmental	All	Italia	Mixed	(Tuni and Rentzelas, 2022)

Table 3 Examples of Literature by Subcategory of Application Cases (continued)

Category	Subcategory	What is evaluated? *	Purpose	ASC Processes	Location	Methodological approach	Reference
7 Beverages	5 wine	Operational efficiency	Productivity	Production	Chile	Quantitative	(Varas *et al*., 2021)
	1 fermented	Risk management	Sustainability	Production	Turkey	Mixed	(Kavsara *et al*., 2020)
	1 tea	Methodology feasibility	Competitiveness	All	China	Mixed	(Chen *et al*., 2021)
6 Dairy	-	Methodology feasibility	Sustainability	Transport	Serbia	Quantitative	(Drews *et al*., 2020)
5 Seafood Products	2 fish	Information system	Traceability	Processing	Holland	Mixed	(Mgonja *et al*., 2013)
	2 seafood	HACCP plan	Food safety	All	China	Quantitative	(Feng *et al*., 2019)
	1 tuna	Value chain	Social sustainability	All	Vietnam	Quantitative	(Thi Nguyen and Jolly, 2018)
3 Others	2 catering	HACCP plan	Food safety	Catering	Belgium	Mixed	(De Boeck *et al*., 2019)
	1 mushroom	Value chain	Customer satisfaction	All	Indonesia	Qualitative	(Suhaeni *et al*., 2021)

*FLW – Food losses and waste. SCM – Supply chain management

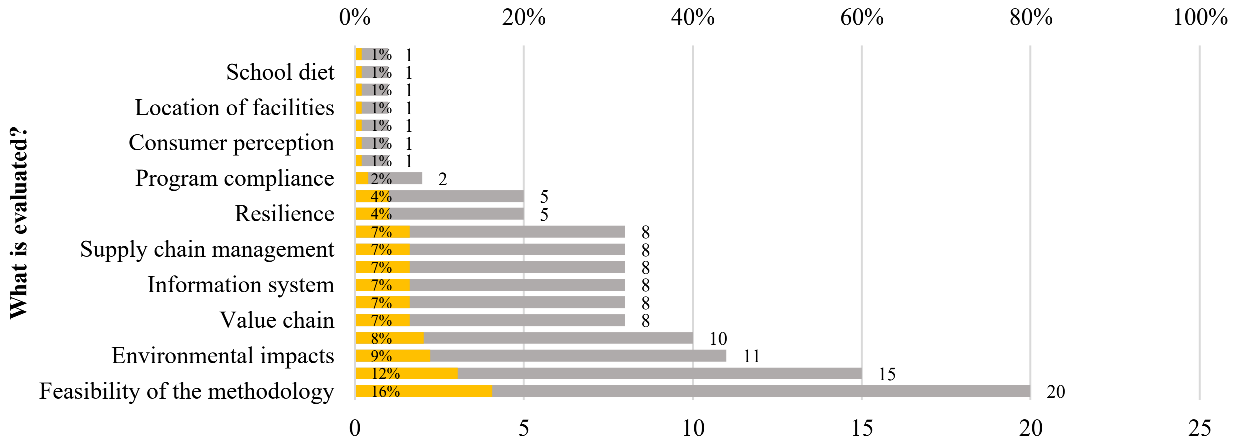

Figure 6 ASC aspects evaluated in the literature

The third most frequent goal is Food Safety (14%), which is defined as the set of actions and measures that must be taken during food production, storage, distribution, and preparation to ensure that it does not represent any health risk once ingested (Feng *et al*., 2019). The goal Productivity, which was addressed in 7% of the literature under assessment, focuses on increasing ASC yield by integrally improving all its processes (Peykani *et al*., 2022). For its part, Competitiveness, which accounts for 4% of the studied literature, is defined as the ability to obtain profits in the market against other competitors (Yadav *et al*., 2021).

3.3 What is Evaluated by ASCPEMs?

In the current evaluation, ASCPEMs were observed to assess 20 aspects of the chain, which encompass process categories, systems, or means of appraisal. As depicted in Figure 6, the most frequently evaluated aspect is the feasibility of the methodology. In this context, case studies have been utilized to demonstrate that the procedure in question fulfills its intended objective (Gambelli *et al*., 2021). The second aspect evaluated pertains to Practices, encompassing actions and decisions made throughout the ASC, such as land preparation, production techniques, irrigation control, transportation, environmental and sustainability concerns, as well as waste, drought, and cold-storage deficiency management (Wei *et al*., 2022). The third aspect focuses on Environmental Impacts, addressing the application of Life Cycle Assessment (LCA) from a circular economy perspective (Stillitano *et al*., 2021). Lastly, the fourth aspect involves quantifying waste and losses along the ASC or in specific processes, particularly concerning the degradation in product quality due to handling and preservation practices (Damiani *et al*., 2021). The Value Chain aspect focuses on coordinating ASC actor operations to ensure value to the final customer (Quiédeville *et al*., 2018). Collaboration addresses the sharing of resources and information to maintain the integrality of supplies (Reklitis *et al*., 2021). Information Systems deal with traceability, i.e., providing historical information about a product through ASC real-time monitoring technology (Farooq *et al*., 2016). Operational Efficiency refers to the degree of resource utilization in the supply chain (Devkota *et al*., 2020). Supply Chain Management evaluates product flow as a function of ASC actors' integration (Hassen *et al*., 2020). Resilience is understood as the ability to adapt to changes, mainly those related to climate (James and Friel, 2015). HACCP Plan Adequacy intends to measure the effectiveness of HACCP in relation to consumer health risk (Feng *et al*., 2019). Program Compliance refers to case studies from the programs "Direct Farm" (DING *et al*., 2015) and "Paddy Land to Dry" (Liang *et al*., 2018), which were conducted in China.

3.4 What Cases Have Been Applied To?

Application cases refer to specific cropping or livestock contexts in which methodologies are validated. A similarity analysis identified 10 application categories, as shown in Table 3 (column Category), along with the number of documents included in each category. The column Subcategory indicates the specific food groups addressed and the number of papers related to each group. Subsequent columns detail each subcategory.

Table 3 indicates that in most studied papers (23%), the methodology is not applied to any specific product. This is often because these works focus on the development and methodology itself. The category Various Foods encompasses products with diverse chemical characteristics. Here, a notable trend is observed in processed foods (such as juices or canned products) with fruits and vegetables.

Regarding the specifics of the Category column, Fruits and Vegetables tend to be evaluated simultaneously. Seeds refer to grains or legumes. The Beef, Pork, or Poultry Meat category concentrates on meat products. The Processed category encompasses products that have undergone physicochemical changes as a result of industrial processing. Lastly, Beverages encompass a range of fermented and tea-based drinks.

3.5 What are the Analysis Methods Applied by ASCPEMs?

The analysis method involves processing collected information to generate a decision, signal, or data output (Amani *et al*., 2022). A total of 48 analysis methods were identified and categorized into 11 groups through a clustering process based on related topics. Table 4 outlines each category in terms of its objectives, the number of

Table 4 Analysis Methods

Category of analysis	Objective pursued in each category	Number of documents	Number of methods	Distribution of the methods across the studied papers*, **
Key Performance Indicators (KPIs)	Quantitative assessment of individual or collective performance through corresponding measuring tools.	79	1	Not applicable
Multicriteria	Evaluation, comparison, and prioritization of decision alternatives through quantitative criteria.	33	9	17 – AHP 5 – TOPSIS 3 – Fuzzy Delphi 2 – ANP 2 – ELECTRE 1 – FAHP 1 – VIKOR 1 – Best Worst Scaling 1 – EDAS
Environmental management	Appraising of environmental aspects and impacts.	26	4	22 – LCA 2 – NUFER 1 – 5R 1 – Resilience
Modeling	Mathematical representation of the operative dynamics of supply chain processes or resources to study complex systems' behavior in the face of situations that are hard to observe directly.	21	10	5 – Predictive 5 – Simulation 2 – Social networks 2 – Arrhenius' kinetics 2 – SEM 1 – DEMATEL 1 – TAM 1 – Clustering 1 – WINGS 1 – System dynamics
Strategic management	Identifying, prioritizing, and exploring opportunities leading to the achievement of strategic objectives.	20	11	8 – SCOR 3 – Policy fulfillment 1 – BSC 1 – IPA 1 – Intelligent contracts 1 – CSR 1 – EWFN 1 – Hayami's method 1 – Sustainable Rice Platform 1 – Stakeholder theory 1 – Cognitive mapping development
Statistics	Establishing whether there is any difference between the means of the studied groups.	13	2	12 – ANOVA 1 – Bayesian network

Table 4 Analysis Methods (continued)

Category of analysis	Objective pursued in each category	Number of documents	Number of methods	Distribution of the methods across the studied papers*, **
Approximate reasoning	Drawing conclusions from incomplete or relatively uncertain information.	9	3	7 – Fuzzy logic 1 – TPB 1 – Spradley's method
Risk	Managing hazard uncertainty through risk identification, evaluation, and assessment, to define reaction plans.	7	2	4 – AMEF 3 – Probability and impact
Uncertainty	Assessing the impact of parameter changes in the face of uncertainty.	7	2	5 – Sensitivity analysis 2 – Shannon's Entropy
Quality	Evaluating the effect of practices and infrastructure on the conservation of food properties.	3	2	2 – Physicochemical and microbiological 1 – Nutritional
Optimization	Determining the values of the variables involved in a process or system to maximize or minimize an objective function under specific parameter constraints.	11	2	7 – DEA 4 – Heuristics

* Multi-criteria: AHP – Analytic Hierarchy Process, TOPSIS – Technique for Order of Preference by Similarity to Ideal Solution, ANP – Analytic Network Process, ELECTRE – Elimination et Choix Tradusiant la Realité, FAHP – Fuzzy AHP, EDAS – Evaluation Based on Distance from Average Solution; Environmental management: LCA – Life Cycle Assessment, NUFER – Nutrient Flows in Food Chains, Environment and Resource Use, 5R – Realign, Reduce, Recycle, Reuse, and Redesign; Modeling: SEM – Structural Equation Modeling, DEMATEL – Decision Making Trial and Evaluation Laboratory, TAM – Technology Acceptance Model, WINGS – Weighted Influence Nonlinear Gauge System; Strategic management: SCOR – Supply Chain Operations Reference, BSC – Balanced Scorecard, IPA: Importance-Performance Analysis, CSR: Corporate Social Responsibility, EWFN – Energy Water Food Nexus; Optimization: DEA – Data Envelopment Analysis; Approximate reasoning: TPB – Theory of Planned Behavior; Risk: FMEA – Failure Modes and Effects Analysis.

** Number corresponds to the number of documents for each method methods and documents within it, and the distribution of methods across the grouped papers.

Performance Indicators (KPIs) were excluded from the methodological distribution due to their specific development for each studied supply chain. However, each remaining category was assigned its most common technique: AHP in the Multi-criteria category, LCA in Environmental Management, predictive or simulation techniques in Modeling, SCOR in Strategic Management, ANOVA in Statistics, DEA in Optimization, fuzzy logic in Approximate Reasoning, Failure Modes and Effects Analysis (FMEA) in Risk assessment, sensitivity analysis in Uncertainty analysis, and physicochemical and microbiological analyses in Quality evaluation.

Additionally, Table 5 lists the analysis methods employed in the studied works. Although some papers merely served as reporting instruments without applying any analytical method, the prevailing trend was to utilize one or two techniques. Papers employing only one method often utilize KPI, followed by LCA. In cases of integrating two methods, the most frequent combinations were KPI with LCA and KPI with ANOVA. Notably, in 31% of instances where KPI was combined with another method, LCA was most utilized as a foundation for subsequent procedures. This highlights researchers' interest in the product life cycle from an environmental perspective, emphasizing parameters like eco-scarcity or eco-indicators. Regarding the simultaneous use of three methods, various combinations were observed, all of which included KPIs. Finally, when four methods were applied, they primarily consisted of multi-criteria techniques such as AHP, TOPSIS, or ELECTRE. What are the Information Sources and Data Collection Techniques Employed by ASCPEMs?

Figure 7 illustrates the hierarchical distribution of the literature regarding information sources and data collection methods, as identified in the current inquiry. The information source refers to the origin of the input data to be analyzed, while the collection method denotes the physical or digital mechanism used to record the information.

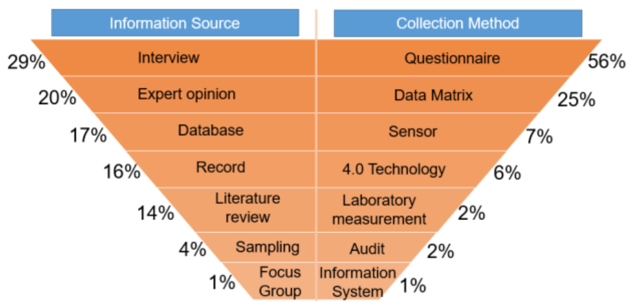

Figure 7 Distribution of studies by information sources and collection methods

Based on the hierarchical arrangement shown in Figure 7, a more in-depth analysis was conducted to examine the reasons behind each data source or collection method. Researchers report that stakeholder interviews are their most frequent source of information due to their ease of use. Conducted using standardized procedures, this type of inquiry is supported by structured or semi-structured questionnaires as the primary data collection method. In the context of ASCPEMs, interviews are the information source employed to evaluate most of the performance features presented in Figure 6: feasibility of methodologies, collaboration, value chain, and compliance with agri-food programs.

Expert Opinions are used to assess risk management, operational efficiency, and information systems. They are often applied when a specific metric is desirable, but there are not enough resources available to obtain it directly. Alternatively, in multi-criteria analysis methods such as AHP, they are necessary to weigh a particular attribute. The most common data collection method employed to record expert opinions is a questionnaire, followed by data matrices.

Databases correspond to public use of official information, for which the most common collection methods are questionnaires and data matrices. These sources are mainly used to assess environmental impact and food waste and losses in combination with LCA. The Data Matrix method refers to the structured representation of data, wherein columns list the attributes being measured and rows correspond to sequential moments in time or process stages. According to the literature, these matrices minimize data preparation time (Demircan and Özcan, 2021).

In turn, Records are physical documents that are usually cataloged in data matrices and are mainly used to evaluate program compliance, HACCP plans, and information systems. The Literature Review is used to build a battery of performance indicators capable of evaluating food loss and waste, as well as ASC collaboration. For its part, Field Sampling allows measuring the effect of variation factors through experimental design. It is primarily used for evaluating operational efficiency and minimizing product loss and waste. When it comes to sampling, the most used data collection method is Laboratory Measurement, which usually implies quantifying physicochemical or organoleptic properties by destructive methods (Venus *et al*., 2013). Finally, the Focus Group is reported for the analysis of consumer perception and compliance with SDGs.ASCPEMs range from simultaneously using more than one information source to not using any, as referenced in Table 6. Cases that do not use information sources are those in which a reference framework is proposed. As can be seen, the common trend is to use only one information source, which, as mentioned above, usually corresponds to interviews, expert opinions, or databases. When two information sources are used, the most frequent combinations are interviews/expert opinions and interviews/records. This is because researchers consider them to be the most accessible methods in the short term. When ASCPEMs resort to three information sources, the most frequently set corresponds to interviews, literature, and databases, which reflects the integration between the business, scientific and public sectors.

Figure 7 presents some other collection methods that are less frequently reported, such as sensors, Industry 4.0 technologies, audits, and information systems. Sensors reported so far are those that measure gas concentration (O_2, CO_2, and C_2H_4) and storage-air thermodynamic properties. In turn, Industry 4.0 technologies are those that digitize the behavior of processes, products, and systems to facilitate

Table 5 ASCPEMs' Literature Uses Several Data Analysis Methods Simultaneously

Number of analysis methods	Number of documents	Document distribution across collection methods	References
0	2	-	(Manning and Soon, 2016)
1	44	22 – KPI	(Tsolakis *et al*., 2018)
		4 – LCA	(Stillitano *et al*., 2021)
		4 – ANOVA	(Shih and Wang, 2016)
		2 – DEA	(Coluccia *et al*., 2020)
		1 – FMEA	(Kavsara *et al*., 2020)
		1 - ANP	(Safaie *et al*., 2019)
		1 – SCOR	(Zhang and Zhu, 2015)
		1 – Fuzzy logic	(De and Singh, 2021)
		1 – Arrhenius kinetics	(Venus *et al*., 2013)
		1 – 5R	(Withers *et al*., 2015)
		1 – Resilience	(Smith *et al*., 2016)
		1 – Spradley's method	(Yuan *et al*., 2019)
		1 – Best-worst scaling	(Karipidis *et al*., 2020)
		1 – Stakeholder theory	(León *et al*., 2021)
		1 – EDAS	(Demircan and Özcan, 2021)
		1 – System dynamics	(Elyasi and Teimoury, 2023)
2	52	10 – KPI and LCA	(Drews *et al*., 2020)
		4 – KPI and ANOVA	(Azevedo *et al*., 2018)
		4 – KPI and AHP	(Kirwan *et al*., 2017)
		3 – KPI, Probability, and Impact Matrix	(Trafiałek *et al*., 2017)
		3 – KPI and policy fulfillment	(DING *et al*., 2015)
		2 – KPI and NUFER	(Ma *et al*., 2019)
		2 – KPI and simulation	(Doménech *et al*., 2008)
		2 – KPI and social networks	(Quiédeville *et al*., 2018)
		2 – AHP and sensitivity	(Lu *et al*., 2020)
		1 – KPI and physicochemical	(Ertan *et al*., 2019)
		1 – KPI and clustering	(Serra and Fancello, 2020)
		1 – KPI and fuzzy logic	(Dania *et al*., 2018)
		1 – KPI and DEA	(Pagotto and Halog, 2016)
		1 – KPI and optimization	(Dabbene and Gay, 2011)
		1 – KPI and Sustainable rice platform	(Devkota *et al*., 2020)
		1 – KPI and smart contracts	(Casino *et al*., 2019)
		1 – KPI and ELECTRE	(Fagioli *et al*., 2017)
		1 – AHP and SCOR	(Gou *et al*., 2013)
		1 – AHP and SEM	(Yontar and Ersöz, 2020)
		1 – ANOVA and Fuzzy Delphi	(Chen *et al*., 2021)
		1 – SCOR and DEA	(Rattanachai *et al*., 2012)
		1 – Fuzzy logic and Bayesian networks	(Zheng *et al*., 2021)
		1 – Predictive and social networks	(Ercsey-Ravasz *et al*., 2012)
		1 – Predictive and physicochemical	(La Scalia *et al*., 2017)
		1 – Predictive and optimization	(Aloui *et al*., 2021)
		1 – Sensitivity and VIKOR	(Pratap *et al*., 2022)
		1 – BSC and IPA	(Gambelli *et al*., 2021)
		1 – TOPSIS and optimization	(Liu *et al*., 2018)
		1 – Fuzzy Delphi and Grey WINGS	(Wang and Zhang, 2022)
3	18	2 – KPI, LCA, and sensitivity	(Harun *et al*., 2021)
		1 – KPI, LCA, and nutritional	(White *et al*., 2011)
		1 – KPI, LCA, and optimization	(Rohmer *et al*., 2019)
		1 – KPI, LCA, and RCE	(Petit *et al*., 2018)
		1 – KPI, LCA, and fuzzy logic	(Djekic *et al*., 2018)
		1 – KPI, LCA, and EWFN	(De Laurentiis *et al*., 2016)
		1 – KPI, LCA, and simulation	(Dong and Miller, 2021)
		1 – KPI, AHP, and fuzzy logic	(Barreca *et al*., 2014)
		1 – KPI, AHP, and SCOR	(Kodrat *et al*., 2020)
		1 – KPI, AHP, and SEM	(Yontar and Ersöz, 2021)
		1 – KPI, DEA, and Shannon Entropy	(Peykani *et al*., 2022)
		1 – KPI, ANOVA, and predictive	(Trigo *et al*., 2023)
		1 – AHP, VIKOR, and DEMATEL	(Raut *et al*., 2019)
		1 – Fuzzy logic, predictive, and Arrhenius	(Feng *et al*., 2019)
		1 – DEA, TOPSIS, and FAHP	(Duman *et al*., 2017)
		1 – ANOVA, TAM, and TPB	(Pappa *et al*., 2018)
		1 – SCOR, ANP, and Hayami	(Marimin, 2018)

Table 5 ASCPEMs' Literature Uses Several Data Analysis Methods Simultaneously (continued)

Number of analysis methods	Number of documents	Document distribution across collection methods	References
4	7	2 – KPI, AHP, SCOR, and FMEA 1 – KPI, AHP, TOPSIS, and ELECTRE 1 – KPI, simulation, AHP, and DEA 1 – KPI, SCOR, TOPSIS, and Shannon entropy 1 – AHP, fuzzy logic, TOPSIS, and FMEA 1 – KPI, simulation, ANOVA, and Cognitive mapping development	(Permana *et al*., 2019) (Lau *et al*., 2017) (Duong *et al*., 2018) (Yadav *et al*., 2021) (Zandi *et al*., 2020) (Reklitis *et al*., 2021)

Table 6 Literature using several simultaneous information sources

Number of information sources	Number of documents	Document distribution across information sources	References
0	16	-	(Dabbene and Gay, 2011),
1	47	14 – Interviews 8 – Experts 7 – Databases 6 – Records 5 – Literature 5 – Field sampling 2 – Focus group	(Quiédeville *et al*., 2018) (Dania *et al*., 2018) (Guo *et al*., 2020) (Kogachi *et al*., 2021) (De and Singh, 2021) (Ertan *et al*., 2019) (Yuan *et al*., 2019)
2	40	10 – Interviews and experts 7 – Interviews and records 6 – Experts and databases 4 – Experts and literature 3 – Interviews and databases 2 – Interviews and literature 2 – Experts and records 4 – Records and databases 1 – Records and literature 1 – Literature and databases	(Mital *et al*., 2018) (Serra and Fancello, 2020) (Abejón *et al*., 2020) (Tsolakis *et al*., 2018) (Dong and Miller, 2021) (Grivins *et al*., 2016) (Varas *et al*., 2021) (Vodenicharova, 2020) (James and Friel, 2015) (Hassen *et al*., 2020)
3	15	4 – Interviews, literature, and databases 3 – Interviews, records, and databases 3 – Interviews, experts, and literature 1 – Records, literature, and sampling 1 – Interviews, records, and literature 1 – Interviews, literature, and sampling 1 – Interviews, records, and experts 1 – Interviews, experts, and records	(Smith *et al*., 2016) (Drews *et al*., 2020) (Zandi *et al*., 2020) (Augstburger *et al*., 2018) (Bloemhof *et al*., 2015) (Gambelli *et al*., 2021) (Thi Nguyen and Jolly, 2018) (León *et al*., 2021)
4	5	1 – Interviews, records, literature, and databases 1 – Interviews, experts, literature, and databases 1 – Interviews, experts, records, and literature 1 – Interviews, records, databases, and sampling 1 – Interviews, experts, records, and databases	(Kirwan *et al*., 2017) (Petit *et al*., 2018) (Djekic *et al*., 2018) (Masotti *et al*., 2022) (Chen *et al*., 2021)

Table 7 Literature makes simultaneous use of several data collection methods

No. of information collection methods	No. of documents	Document distribution across information collection methods	References
0	11	-	(Gou *et al*., 2013)
1	94	64 – Questionnaires 24 – Data matrixes 3 – Sensors 2 – Laboratory measurement 1 – Internal auditing	(Kokemohr *et al*., 2022) (Kruger *et al*., 2022) (Djekic *et al*., 2018) (Ertan *et al*., 2019) (Manning *et al*., 2008)
2	14	8 – Questionnaires and data matrices 3 – Sensors and IoT 1 – IoT and blockchain 1 – Questionnaires and sensors 1 – Sensors and laboratory measurement	(Thongmai *et al*., 2021) (Bogataj *et al*., 2017) (Casino *et al*., 2019) (Doménech *et al*., 2008) (Venus *et al*., 2013)
3	3	2 – Questionnaires, data matrices, and audit 1 – Sensors, RFID, and ePedigree	(De Boeck *et al*., 2019) (Farooq *et al*., 2016)
4	1	Questionnaires, IoT, big data, and ERP	(Yadav *et al*., 2021)

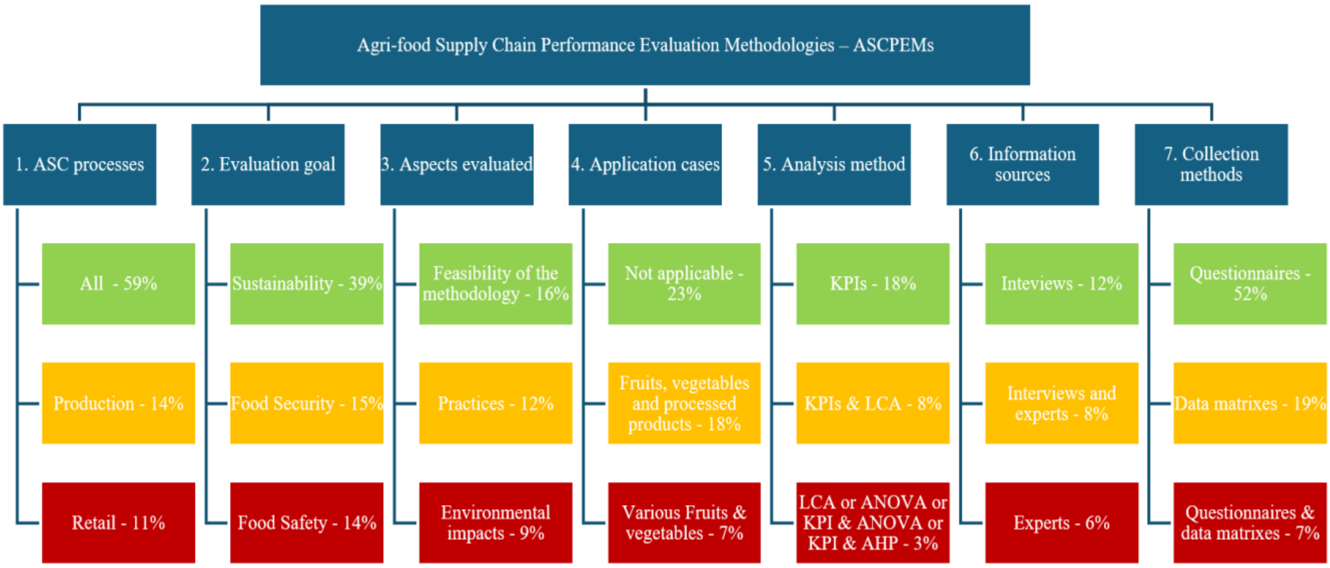

Figure 8 Top 3 for each characteristic of ASCPEMs

real-time data availability and information-based decision making (Onwude *et al*., 2020). Broadly speaking, the most frequently used Industry 4.0 technologies are artificial intelligence, augmented and virtual reality, big data, blockchain, machine learning, cloud computing, Internet of Things (IoT), robotics, and automation (Lezoche *et al*., 2020). Specifically regarding ASCPEMs, the most frequently reported Industry 4.0 technologies are IoT and big data. In turn, business information systems are mechanisms that integrate and interconnect processes to track them and facilitate decision-making (Yadav *et al*., 2021). Of these systems, Enterprise Resource Planning - ERP – and ePedigree are the most applied ones in ASCPEMs contexts.

Complementing the above, the studied literature was also analyzed in terms of the simultaneous use of one or more collection methods. Table 7 shows that 11 works do not use any such method, in correspondence with the lack of a specific ASCPEMs application context. It is also observed that the dominant trend is to use a single collection method (76% of the literature), questionnaires and data matrices being the most used ones. On the other hand, 11% of the papers make simultaneous use of two collection methods, the main combinations being questionnaire/data matrix and sensors/IoT.

4. DISCUSSIONS

Given that the research aims to systematically review the characteristics of Agri-food Supply Chain Performance Evaluation Methodologies (ASCPEMs) and considering the current lack of literature that has similarly characterized methodologies, the discussion of the results centers on comparing the trends observed in the methodologies with the results and complexities documented in the PE within the ASC, as described earlier.

To streamline the conclusion regarding the tendencies of ASCPEMs, Figure 8 depicts the percentage distribution of the 123 identified methodologies, focusing on the top 3 subcategories for each considered characteristic. We concluded that the predominant scope of ASC evaluation, accounting for 59% of the literature, encompasses all chain processes under the "from farm to table" premise.

This involves the acquisition of supplies and raw materials, agricultural production, industrial processing, storage, post-harvest handling, distribution, retail, and marketing. Following this, production (14%) and retail (11%) represent the subsequent most frequently evaluated processes by ASCPEMs. These findings regarding the scope of the methodologies are corroborated by Fagioli *et al.* (2017), who argue that evaluating performance in food supply necessitates measuring the processes involved in the product flow from farm to table.

Another trend observed in ASCPEMs is the clear emphasis on sustainability as the predominant goal (39%), encompassing economic, social, and environmental aspects simultaneously. Following closely are food security (15%) and food safety (14%) as key objectives. Ali *et al.* (2024), Wei *et al.* (2022) and León *et al.* (2021) argue that the primary achievements sought through PE in an ASC include ensuring food security, maintaining product quality (strongly linked to food safety), improving production efficiency, managing cold chains effectively, and promoting sustainability.

To measure the attainment of these objectives, the prevailing methodological approach involves a blend of techniques, frequently integrating both quantitative and qualitative methodologies. This observation resonates with Quiédeville *et al.* (2018) who illustrated that the amalgamation of these methodologies, termed mixed methodologies, is highly advisable in the agricultural context, owing to the diverse and interconnected nature of elements within the ASC, necessitating a holistic and comprehensive assessment approach.

In terms of the aspects under evaluation, Figure 8 indicates a trend where there is a focus on assessing the feasibility of the ASCPEMs themselves (16%), followed by the cultural practices of the actors (12%) involved in the ASC, and finally, environmental impacts. Among the practices most evaluated are the actions and decisions taken throughout the ASC, including land preparation, production techniques, irrigation control, transportation, environmental and sustainability issues, as well as waste, drought, and cold-storage-deficiency management. Varas *et al*. (2021) and Tsolakis *et al*. (2018) argue that validation in one context does not necessarily ensure consistency of results in another, as existing methodologies lack generalizability for broader application.

Another significant characteristic associated with the scope is the range of products considered in the analysis, often referred to as application cases. In this regard, there is a tendency to propose methodologies theoretically without validation (23%), focusing more on a report. Additionally, there is a trend toward evaluating multiple food categories simultaneously (18%), reflecting the composition of a typical food supply, with a primary focus on studying various fruits, vegetables, and processed products concurrently. According to Dong and Miller (2021), this is necessary in evaluating agri-food supply chain performance to account for the various categories comprising the family basket.

On the other hand, there is a strong tendency to apply KPIs as the method of analysis. It was also observed that each methodology is associated with a specific battery of indicators, for example, the case of KPIs and LCA (8%), where the analysis is directed towards environmental sustainability. Among the analysis methods, four options hold the third position: LCA, ANOVA, KPI and ANOVA, and KPI and AHP. This suggests a trend towards constructing and implementing KPIs that span the product lifecycle, with prioritization or weighting done through a multicriteria approach like AHP. In certain instances, statistical significance is assessed to validate hypotheses using ANOVA. Serra and Fancello (2020) identified KPIs as one of the most utilized methods for measuring and analyzing logistical performance. This is because KPIs offer a precise understanding of which areas or processes of the supply chain are not aligned with the established objectives.

In current ASCPEMs contexts, information sources and data collection methods typically entail lengthy application processes. Consequently, by the time the information is analyzed, the dynamics of the chain may have shifted due to demand-supply fluctuations. Stakeholder interviews are the most used information source (12%), while questionnaires dominate as the data collection method (52%).

In addition to the above, this research identified, for each of the selected studies, the limitations highlighted by the authors regarding the ASCPEMs addressed. Based on the frequency analysis of these reported limitations, a roadmap is proposed to serve as a guideline for future research. Figure 9 presents the main limitations, organized according to their percentage of occurrence relative to the total number of selected publications. This order defines the most appropriate progression of the proposed roadmap, as it follows a scientific and technological rationale that has the potential to ensure both the validity and scalability of future results.

A progressive roadmap is proposed to guide the advancement of ASCPEMs. The first phase focuses on validating the ASCPEMs using an alternative analytical method, taking as reference the approaches listed in Table 4. This step establishes the foundation by confirming the robustness of the initial results through complementary techniques, ensuring that the model does not depend on a single methodological approach and thereby reinforcing its credibility.

The second phase involves validating the ASCPEMs in a different agri-food supply chain or contextual setting to assess their applicability across diverse environments. This validation enables the identification of transferability and context-specific factors affecting performance. Once these validations are achieved, the issue of limited generalization is naturally addressed. During this stage, it is crucial to recognize and document extrapolation constraints to prevent misinterpretation and promote responsible application. Current methodologies generally lack a clear structure for reporting such implementation-related limitations.

The fourth phase extends the scope of the ASCPEMs to all processes within the agri-food supply chain, aiming to develop an integrated framework that spans from production to consumption. This expansion ensures a controlled and evidence-based evolution of the system.

Finally, in the fifth phase—representing the maturity stage—Industry 4.0 technologies should be incorporated once the model has been validated, contextualized, and extended. Disruptive technologies such as the Internet of Things (IoT), Artificial Intelligence, blockchain, and digital twins can enhance traceability, automation, and real-time decision-making, thereby consolidating an advanced and scalable solution.

In summary, the trends identified in ASCPEMs reveal the predominance of farm-to-table scopes, sustainability-oriented objectives, and KPI-based approaches, alongside methodological limitations that constrain their generalization and transferability. To address these gaps, the proposed five-phase roadmap—covering methodological validation, contextual validation, generalization, scope extension, and technological integration—ensures both scientific rigor and practical scalability, supporting the evolution of ASCPEMs toward comprehensive and technologically advanced performance evaluation frameworks.

Overall, the synthesis of findings in this review provides valuable theoretical and practical contributions to the field of agri-food supply chain performance evaluation. From a theoretical perspective, it consolidates fragmented knowledge by identifying and structuring seven key characteristics that define how ASCPEMs have been conceptualized and applied. This framework enables a comprehensive understanding of methodological diversity. It reveals emerging trends, such as the predominance of farm-to-table evaluations, the emphasis on sustainability, and the increasing adoption of mixed methods supported by key performance indicators. From a practical standpoint, these results serve as a reference guide for researchers, practitioners, and policymakers to make informed methodological and strategic decisions in performance evaluation processes. The proposed roadmap further enhances the practical contribution by outlining a logical sequence for validating and scaling methodologies—from ensuring analytical robustness to integrating Industry 4.0 technologies—thus bridging academic insights with actionable implementation pathways in real supply chain contexts.

Figure 9 Proposed roadmap for future work on ASCPEMs

5. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This review systematically examined and synthesized the literature on Agri-food Supply Chain (ASC) performance evaluation methodologies, identifying 123 studies and classifying them across seven defining characteristics: ASC processes involved, evaluation goals, aspects evaluated, application cases, analysis methods, information sources, and data collection methods. The analysis revealed dominant trends, including the prevalence of farm-to-table evaluation scopes, a strong orientation toward sustainability as a multidimensional goal, and the recurrent use of KPI-based and mixed-method approaches. Collectively, these findings indicate a progressive evolution toward more integrated and holistic frameworks for assessing ASC performance.

Some limitations should be acknowledged. The diversity of the reviewed methodologies—each shaped by specific socioeconomic and contextual factors—limits the generalizability of the findings across all supply chain configurations. Furthermore, the review was restricted to peer-reviewed and indexed publications, which may have excluded valuable contributions from technical reports, policy papers, or non-English sources. The classification of methodologies relied on the information reported by authors, which varied in depth and transparency, potentially affecting the precision of comparisons. Finally, considering the rapid development of digital and data-driven technologies in the agri-food sector, some patterns identified here may evolve rapidly, emphasizing the need for ongoing monitoring and updates.

Future research should therefore focus on several key directions. First, continuous updates of the literature are essential to capture methodological advances and the incorporation of emerging technologies. Second, validation of existing methodologies through alternative analytical approaches and their application in diverse ASC contexts is required to enhance robustness and transferability. Third, there is a need for standardized implementation guidelines that facilitate practical adoption and ensure methodological comparability across studies. Finally, as agri-food supply chains continue to digitalize, the integration of Industry 4.0 technologies—such as the Internet of Things, artificial intelligence, blockchain, and digital twins—will be fundamental to achieving real-time monitoring, traceability, and data-driven decision-making in performance evaluation.

In conclusion, this review provides a structured and updated synthesis of ASC performance evaluation methodologies, identifies key trends and limitations, and outlines a coherent roadmap for advancing methodological rigor, contextual applicability, and digital transformation in future research.

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