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Systematic Review

Risks in food supply chains and strategies to mitigate them: a systematic literature review

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Abstract

Paper aims: This study aimed to identify the main risks present in Food Supply Chains (FSCs) and the strategies employed to mitigate them through a Systematic Literature Review (SLR).

Originality: The originality of this research lies in the systematization of risks and mitigation strategies from an extensive international body of literature, providing an integrated and updated perspective on the challenges facing FSCs.

Research method: The review used PRISMA and Joanna Briggs Institute (JBI) protocols. Sources included the Scopus, Web of Science, and Google Scholar databases, along with grey literature.

Main findings: The study identified fourteen key risks, including disruptions, forecasting failures, and operational, environmental, logistical, and intellectual property risks. Mitigation strategies were grouped into proactive, reactive, and concurrent approaches, and involved technologies such as IoT, blockchain, and big data, as well as practices like supplier diversification, traceability, and sustainability.

Implications for theory and practice: Findings support managerial and policy decision-making and contribute to building more resilient, efficient, and secure FSCs. They also highlight the need for further research tailored to the Brazilian context and reinforce the importance of digital and sustainable strategies in supply chain risk management.

Keywords

Resilience. Disruptions. Proactive. Reactive. PRISMA.

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Conflict of Interest
The authors have no conflict of interest to declare.

Ethical Statement
This study did not involve human participants and therefore did not require ethical approval.

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1. Introduction

Food Supply Chains (FSCs) represent a series of interconnected processes encompassing all stages, from agricultural production through processing, commercialization, and distribution to the final consumption of food (Nakai, 2018; Zhao et al., 2020). Given their importance in providing sustainable, accessible, safe, and sufficient food, ensuring their effective functioning in an increasingly dynamic and volatile business environment becomes essential (Zhao et al., 2020).

Over the years, FSCs have faced numerous challenges, including supply disruptions (Ali et al., 2019). These chains are becoming increasingly complex and, therefore, more susceptible to various vulnerabilities and risks (Zhao et al., 2020). Supply chain disruption is a failure often caused by unforeseen incidents or risks. Contemporary supply chains are globalized, complex, and extensive, making them more vulnerable (Ali et al., 2024). The increasing complexity, driven by demand, digital business models, and globalization, calls for innovative approaches (Gruzauskas et al., 2023).

Risk management has become an emerging field with the rise of disruptive events caused by human and natural disasters. Furthermore, environmental concerns, cost reduction, profitability, and social impacts in operations have prioritized sustainable supply chains (Bassett et al., 2021). Studying risk mitigation is essential, as operations can either generate vulnerabilities or foster resilience (Ivanov et al., 2014). Risks range from production disruptions to food safety issues impacting operations and reputations. Santeramo et al. (2021) highlight these risks for both perishable and non-perishable foods. Bogadi et al. (2016) and Jurica et al. (2019) address intentional contamination, fraud, and terrorism, evidencing the severity of such challenges.

Despite some studies on supply chain risks, there is still a lack of research focused specifically on FSCs, especially concerning the variety of risks, mitigation strategies, types of strategies, and the Brazilian context. Ali et al. (2023) explore the relationship between knowledge, risk management culture (RMC), and resilience. Ali & Govindan (2023) analyze Industry 4.0 technologies and their impact on operational risks such as supply and demand, finance, and transportation. Jacobi et al. (2019) address the resilience of food systems, emphasizing production-related risks. However, these insights do not always translate into practical strategies, highlighting the need for innovative policies and support for vulnerable groups.

Additionally, Fan et al. (2021) investigate the convergence of risks such as climate crisis, resource degradation, biodiversity loss, disease outbreaks, food insecurity, trade shocks, conflicts, and political instability, emphasizing the urgency of addressing them to ensure sustainable and resilient food systems.

Given this scenario, this study seeks to answer the following research question: What are the main risks in food supply chains, and what strategies can be implemented to mitigate them?

This study aims to conduct a systematic literature review to identify the key risks in food supply chains (FSCs) and the corresponding mitigation strategies. While the primary focus is global, the study highlights relevant aspects of Brazil when appropriate. Specifically, the study aims to: (i) Analyze the underlying causes of risks in food supply chains; (ii) Relate these risks to food security and their impacts on product quality and operational efficiency; (iii) Propose recommendations or best practices to enhance the resilience of FSCs against the identified risks; and (iv) Present a synthesis of the main risks in food supply chains and the strategies to address them.

This article is structured into four sections to meet the proposed objectives, including this introduction. The second section presents the methodological procedures for conducting the Systematic Literature Review (SLR). The third section presents the results and discussion. Finally, the fourth section presents the conclusions, contributions, research limitations, and an agenda for future research.

2. Method

This study employs a systematic literature review approach following the recommendations of the international guide Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Munn et al., 2019) and the method proposed by the Joanna Briggs Institute (JBI). The systematic literature review (SLR) allows the recovery of accumulated knowledge from previous studies while facilitating the development of in-depth research on a specific topic.

For the analysis, the materials that comprise the corpus of articles in this review were collected from the following databases: Scopus, Web of Science, and Google Scholar. The first two were chosen as multidisciplinary databases with rigorous indexing processes, and the latter were used to aggregate various studies related to the topic.

To define the scope of research, the PICO acronym was used (P - Problem or Population; I - Intervention; C - Comparison or Control; O - Outcomes), as it best fits the central research question of this review: What risks exist in food supply chains, and what strategies can be used to mitigate them?

The following thesauri were used to find synonyms and related terms to the keywords and enhance both the breadth and accuracy of academic searches: IEEE, ERIC, and UNESCO. These specialized thesauri provide a list of relevant terms and concepts in the fields of engineering, education, and social sciences, respectively.

The keywords referring to the items of the PICO acronym were used to construct the search strategy. The search strategy included the following terms: ("Supply chain" OR "Distribution," "Network" OR "Logistics" OR "Value chain") AND ("Risks" OR "Perils" OR "Dangers" OR "Threats") AND ("Food industry" OR "Food sector" OR "Food Manufacturing sector" OR "Food processing industry" OR "Food Distributors" OR "Food suppliers" OR "Food wholesalers") AND ("Mitigation" OR "Minimization"). The detailed search strategy and the full list of included articles are provided in the Supplementary Material.

All works were preselected regardless of citation count, H-index, or journal quality. There were no time restrictions regarding the publication date. The initial search yielded 124 articles from Scopus (title, abstract, and keywords), 28 from Web of Science (topic), 87 from Google Scholar (no filters), and four from grey literature sources, totaling 243 articles. The PRISMA protocol was adopted to structure the Bibliographic Portfolio (BP) (Figure 1) (Munn et al., 2019).

The materials were exported to Parsifal software (243), where 41 duplicates were removed, and 62 articles were excluded after reading the title and abstract. Based on the criteria presented below, 136 were left for full-text reading. Of these, 49 were excluded after full reading. Finally, four studies were added through the snowball sampling technique, as they proved relevant to the supply chain field. With the inclusion of these studies, the total number of reviewed papers became 91.

Moreover, Table 1 presents the questions that guided the final decision regarding the inclusion of articles in the corpus of this review. A bias analysis was conducted using a checklist based on the JBI Critical Appraisal Checklist for Qualitative Research, (The Joanna Briggs Institute, 2017), with some adaptations specific to this study, indicated in questions 7, 8, and 9. The exclusion criteria (EC) for the articles were: i) Articles not directly related to the food supply chain or its associated risks; ii) Studies that address only issues related to agricultural production or food processing without considering logistics and distribution; iii) Documents not available in digital format or that could not be accessed through the selected databases; iv) Duplicated or redundant studies.

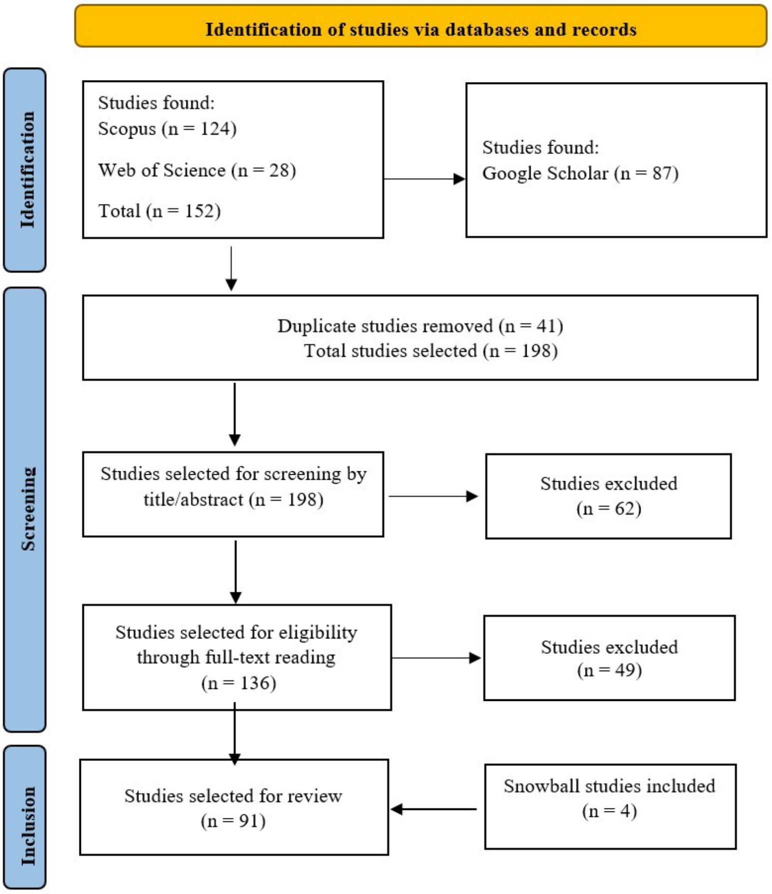

Figure 1. PRISMA Flowchart.

Table 1. Checklist for Article Bias Analysis.

No.	Question	Source
1	Does the article address the theme of risks in food supply chains?	Criterion for inclusion of the article in the sample
2	Does the article address the theme of risks in food supply chains and/or strategies to mitigate them?	Criterion for inclusion of the article in the sample
3	Is there congruence between the research methodology and the research objectives?	JBI Checklist for Qualitative Research
4	Is there congruence between the research methodology and the data collection methods?	JBI Checklist for Qualitative Research
5	Are the research objectives clearly defined and aligned with the results presented?	JBI Checklist for Qualitative Research / adapted by the author
6	Are the study subjects or food supply chain environments described in detail?	JBI Checklist for Qualitative Research / adapted by the author
7	Does the study provide recommendations or best practices to strengthen and/ or mitigate risks in food supply chains?	Authors
8	Were strategies to deal with risks in food supply chains addressed?	Authors
9	Were recommendations made to strengthen management practices and mitigate risks in food supply chains?	Authors
10	Are the study conclusions clearly presented and based on the results obtained?	JBI Checklist for Qualitative Research

The articles were included if they met the criteria evaluated using the checklist in Table 1, considering: thematic relevance (direct focus on risks in food supply chains – FSCs – or mitigation strategies); methodological congruence (coherence between objectives, methodology, and data collection); clarity of objectives (explicit definition and alignment with results); context detailing (thorough description of the FSC subjects or environments); and practical recommendations and mitigation strategies (suggestions to strengthen resilience or manage risks, a critical inclusion criterion).

For article exclusion, the following aspects were considered: no direct relation to the topic (risks in food supply chains – FSCs); restricted focus (only agricultural production or processing, without logistics/distribution); inaccessibility in the selected databases; or duplication/redundancy. The searches in Google Scholar captured 87 articles without prior filters. Subsequently, the same rigorous criteria applied to the other databases (Scopus and Web of Science) were used: duplicate removal via Parsifal, title/abstract screening, full-text reading, and quality assessment using Parsifal.

The data were systematized using the Parsifal platform, applying a qualitative assessment based on a binary scale (Yes/No) for each criterion. The evaluation was conducted independently by reviewers, and the data were subsequently consolidated. The quality assessment criteria of the studies were entered into the Parsifal platform, which enables the structured management of systematic reviews, and are described in Table 1. The Quality Assessment Score was configured with a maximum score of 100, adopting the following classification ranges: above 70% (high quality), between 50% and 69% (moderate quality), and below 49% (low quality). Only articles with a score equal to or greater than 70% were selected for analysis. The assessment was conducted independently by the authors. Questions 7, 8, and 9 were defined as critical for the inclusion or exclusion of articles to mitigate potential biases resulting from subjectivity in the interpretation of qualitative criteria. These questions assessed whether the studies presented practical recommendations for strengthening resilience, specific risk mitigation strategies, and relevant trends or technological innovations applied to risk management in food supply chains.

After the bias analysis was conducted using the Parsifal software, the articles were exported, and a spreadsheet was created in Excel for data analysis. Once the portfolio was selected, the next step involved reading and analyzing the articles. The evaluation criteria adopted for the content analysis are summarized in Table 2.

Table 2 presents criteria such as the type of food (perishable, semi-perishable, and non-perishable), considering that perishability impacts supply chain management, logistical risks, and storage and transportation strategies. The chain's complexity is classified as simple, with direct suppliers and/or customers, or extensive, involving a second tier. The country where the study was conducted and the methods used (quantitative, qualitative, or mixed) are also considered.

The analysis also addresses the types of risks identified and the mitigation strategies proposed to deal with the reported risks. There are three types of risk mitigation strategies: proactive, concurrent, and reactive (Ali et al., 2019; Zavala-Alcívar & Verdecho, 2020). Proactive approaches are implemented to reduce risks before they occur, anticipating potential issues and taking preventive measures (Gouda & Saranga, 2018). Concurrent strategies are applied during an event, enabling a quick and effective response to maintain operational continuity (Ali et al., 2019; Zavala-Alcívar & Verdecho, 2020). Reactive strategies, in turn, are not activated before the event occurs but are executed afterward to minimize the effects and/or the likelihood of recurrence (Ali et al., 2019).

3. Results and discussion

3.1. Bibliometric analysis

The bibliometric analysis considered several aspects, including the number of publications per year (Figure 2), most cited authors (Figure 3), and countries (Table 3). These criteria allow us to identify research trends and contributions to the field.

Table 2. Criteria for Content Analysis.

Criterion	Subcriterion	Description
Types of food	Perishable	Foods with a short shelf life, such as fruits, vegetables, meat, and dairy products.
	Semi-perishable	Foods with a longer shelf life, such as grains, canned foods, and dry products.
	Shelf-stable or non-perishable	Foods that can last from three months to three years with proper storage.
Supply chain complexity	Simple	Short chains with few intermediaries, usually local.
	Extensive	Long chains with many intermediaries, often global.
Method	Quantitative	Use of numerical and statistical data for analysis.
	Qualitative	Use of non-numerical data, such as interviews and case studies.
	Mixed	Combination of quantitative and qualitative methods.
Risks	Risk description	Types of risks identified in the supply chain, such as interruptions or contamination.
Mitigation strategies	Proactive, reactive, and concurrent strategies	Proposed strategies to mitigate identified risks.

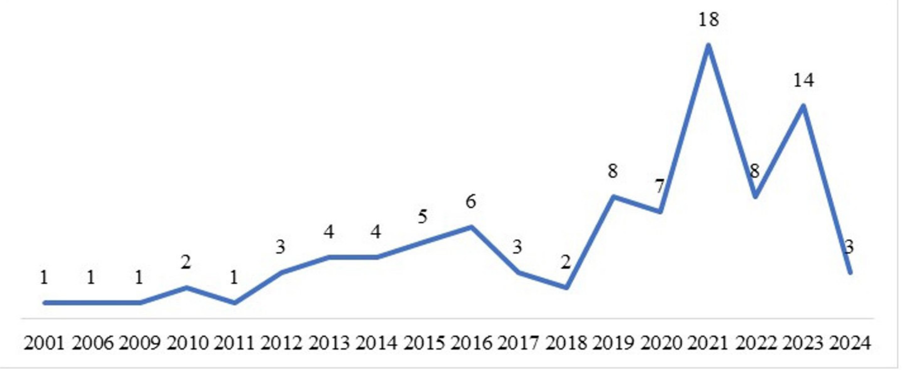

Figure 2. Number of publications per year.

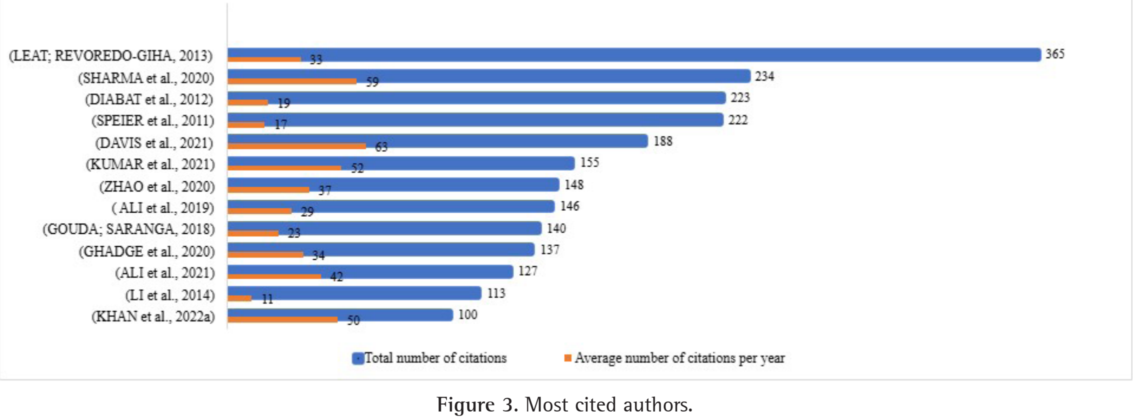

Figure 3. Most cited authors.

Table 3. Countries with the highest number of studies in the sample.

Country	Number of studies	Types of food
India	8	Agrifood, general food, fresh food, processed food, cereals, and grains
Indonesia	6	Agrifood, general food, and fruits
Malaysia	6	General food
United States	5	Agrifood, general food, and fruits
United Kingdom	5	Agrifood and general food
Tunisia	4	Agrifood and processed food
Australia	3	Agrifood, processed food, and vegetables
China	2	Processed food, and dairy products
Italy	2	Agrifood

Figure 2 shows the growth of publications on food supply chains, driven by the increasing complexity of these chains, technological advancements, global events, and concerns about safety and sustainability. From 2019 onwards, there is a sharp increase, peaking in 2021, reflecting the impact of the COVID-19 pandemic on research in this area. The following years maintained high numbers, indicating continued interest in the field. Figure 3 highlights the authors with more than 100 citations in the bibliometric analysis, showcasing the most influential works on risk management in food supply chains.

The article by Ho et al. (2015), with 900 citations, provides a comprehensive analysis of practices and strategies for mitigating operational risks and is the most referenced in the field. Dolgui et al. (2018) discuss the ripple effect of disruptions, with 825 citations, making it the second most cited article. Leat & Revoredo-Giha (2013), with 365 citations, explore resilience in supply chains, while Sharma et al. (2020) address the impact of modern technologies with 234 citations. Diabat et al. (2012) and Speier et al. (2011) emphasize integrated risk assessment models and logistics disruptions, with 223 and 222 citations.

Davis et al. (2021) , with 188 citations, highlight storage infrastructure, while Kumar et al. (2021) present empirical studies with 155 citations. Zhao et al. (2020) and Ali et al. (2019) focus on emerging technologies and collaboration, with 148 and 146 citations. Other important studies include Ghadge et al. (2020), with a risk management framework (137 citations); Gouda & Saranga (2018), emphasizing sustainability (140 citations); and Ali et al. (2024), exploring IT methodologies (127 citations). Li et al. (2014) and Khan et al. (2022a) highlight resilience and specific strategies for developing countries, with 113 and 100 citations, respectively.

Another aspect evaluated in the study was the relevance of countries in research. The geographic diversity presented in Table 3 highlights the broad reach of studies in the field.

The 91 studies analyzed reflect the topic's global relevance, with particular emphasis on India, Indonesia, and Malaysia. In addition, 27 papers have an international focus. The geographic diversity contributes to a broader understanding of risks and mitigation strategies, supporting regional adaptation and sharing best practices to strengthen resilience in food supply chains (FSCs).

3.2. Scope analysis

The analysis revealed numerous factors considered in the reviewed studies, such as food types (perishable, semi-perishable, and non-perishable), supply chain complexity (simple, medium, or extensive), countries where the studies were conducted, methods used (qualitative, quantitative, and mixed), types of risks, and mitigation strategies.

Among the 91 studies analyzed, four (5%) focus on non-perishable foods (Davis et al., 2021; Ramos et al., 2021; Rathore et al., 2017, 2021), while 15 (18%) address perishable foods, such as fruits, vegetables, and dairy products (Ali & Gurd, 2020; Hetzenauer et al., 2023; Hoang et al., 2023; Julien-Javaux et al., 2019; Pereira et al., 2020). Another 11 studies examine semi-perishable foods (Elmsalmi et al., 2021; Onyeaka et al., 2023; Silva et al., 2023; Tavakoli Haji Abadi & Avakh Darestani, 2023).

Additionally, 61 (77%) articles address all three categories—perishable, semi-perishable, and non-perishable foods (Ali et al., 2021; Azmi et al., 2021a; Kumar et al., 2021; Kuizinaitė et al., 2023; Luo et al., 2022; Mohezar et al., 2023; Sid et al., 2021). One study focuses on high-value products, including dairy, meat, fish and seafood, alcoholic beverages, and oils (Maritano et al., 2024).

Perishable foods are highly susceptible to spoilage and require fast, efficient supply chains to maintain quality. Natural disasters and environmental risks, as highlighted by Ramos et al. (2021), significantly impact these chains. Sun et al. (2023) emphasize risk management and collaboration, while Kuizinaitė et al. (2023) highlight preservation methods, freezing, drying, converting raw materials into semi-processed products, and modified atmosphere packaging systems.

Although non-perishable foods have excellent durability, they are still subject to risks such as production failures, inadequate inventory, low quality, technological risks, natural disasters, communication failures, and storage limitations. Mitigation strategies include using technologies such as RFID, metal detectors, X-ray systems, optical sorting, and improved storage (Rathore et al., 2017; Sharma et al., 2022). Adopting Good Manufacturing Practices (GMP), strict supplier control, audits, traceability, recalls, and continuous employee training are key to ensuring food safety (Onyeaka et al., 2023).

Regarding supply chain complexity, 89 out of the 91 studies address extensive (high-complexity) chains characterized by multiple actors and global interactions, as seen in Ramos et al. (2021) and Sun et al. (2023). Only two studies focus on medium-complexity chains with moderate interdependence and coordination (Cui & Basnet, 2015; Lambert et al., 1998).

Forty-one studies employed qualitative approaches, 32 quantitative, and 18 mixed methods. Among the quantitative methods, techniques such as Grey-AHP, Grey-TOPSIS, PLS-SEM, and SEM stand out. For example, Rathore et al. (2017) used Grey-AHP and Grey-TOPSIS for risk assessment, while Sun et al. (2023) applied PLS-SEM to investigate supply chain resilience.

Qualitative methods include literature reviews (Trmčić et al., 2021), case studies (Leat & Revoredo-Giha, 2013; Pereira et al., 2020), Fuzzy Linguistics (Sharma et al., 2020), and Grounded Theory (Hoang et al., 2023). These methods explore and understand supply chain risks' more subjective and contextual aspects. Case studies and interviews are commonly used to gain insights into specific problems and their solutions, as shown in Sharma et al. (2020).

Mixed methods combine qualitative and quantitative approaches. ISM-MICMAC, for example, is used to identify and prioritize risks in agricultural supply chains by combining both analytical types to develop effective mitigation strategies (Diabat et al., 2012; Hachicha & Elmsalmi, 2014; Ramos et al., 2021; Srivastava et al., 2015). Other mixed methods include thematic analyses combined with fuzzy techniques, such as TISM analysis and fuzzy MICMAC (Astuti et al., 2014; Chaudhuri et al., 2016; Khan et al, .2022b; Pardaev et al., 2023; Magalhães et al., 2022; Sharma et al., 2020, 2022).

3.3. Risks and mitigation strategies in food supply chains

To meet the objective of the systematic literature review (SLR), the reviewed literature was analyzed to identify the main risks in food supply chains (FSCs) and strategies to mitigate them.

3.3.1. Analyze the underlying causes of risks in food supply chains

The SLR identified several causes of risks in FSCs, including natural disasters (earthquakes, storms, floods, and climate change) and artificial risks (terrorist attacks and sabotage), which can disrupt operations and result in significant food losses (Reddy et al., 2016; Wahyuni et al., 2021).

Operational failures and IT system malfunctions negatively impact inventory management, production, and logistics, resulting in delays, loss of perishable goods, and waste (Ali et al., 2019; El Ayoubi & Radmehr, 2023). The shortage of qualified personnel also increases operational risks, affecting food quality and efficiency due to production errors, improper handling, and failures in food safety protocols (Ali et al., 2019).

Supply and transportation issues lead to delays, losses, and increased costs, exacerbated by reliance on single suppliers or specific regions (El Ayoubi & Radmehr, 2023; Zhao et al., 2020). Legal and regulatory risks cause disruptions, penalties, and reputational damage, harming food quality and consumer trust (Ali et al., 2019).

3.3.2. Link risks to food safety and impacts on product quality and operational efficiency

The identified risks in FSCs significantly impact food safety, product quality, and operational efficiency. Natural disasters and operational failures lead to food contamination, resulting in recalls and substantial losses. Moreover, disruptions in these chains can compromise the availability of safe and nutritious food, affecting consumer health (Reddy et al., 2016; Wahyuni et al., 2021).

Lack of qualified personnel, IT system failures, and supply and transportation disruptions lead to the production of low-quality food. This affects customer satisfaction and company reputation and may cause financial losses due to defective products or recalls (Ali et al., 2019).

Supply chain disruptions, transportation issues, and regulatory failures increase operational costs and reduce efficiency. Dependence on specific suppliers and lack of contingency planning aggravate these problems, resulting in delays and inefficiencies throughout the supply chain (El Ayoubi & Radmehr, 2023; Zhao et al., 2020).

3.3.3. Propose recommendations or best practices to strengthen the resilience of food supply chains against identified risks

To strengthen the resilience of FSCs against identified risks, several recommendations and best practices are necessary. Implementing formal risk management systems is essential, including advanced technologies for monitoring, data analysis, and automation (Ali et al., 2019; Zhao et al., 2020). Reducing dependence on a single supplier, diversifying the supplier base, and collaborating with stakeholders increase resilience (Ali et al., 2019; El Ayoubi & Radmehr, 2023). Emergency and contingency response plans minimize disaster impacts and ensure food safety (Reddy et al., 2016). Improving infrastructure, training staff, and adopting promising practices reduce operational risks (El Ayoubi & Radmehr, 2023).

Industry 4.0 technologies, such as IoT, big data analytics, blockchain, robotics, RFID, and traceability, increase visibility, traceability, and coordination (Ali et al., 2024; Hoang et al., 2023). Sustainable practices reduce environmental impacts and strengthen responsiveness (Ali et al., 2019). These technologies have been strategically applied to mitigate risks in food supply chains (FSCs), particularly those involved in handling perishable and high-value products. According to Ali et al. (2024), in the Australian food industry, tools such as IoT, big data, cloud computing, and autonomous robots have contributed to reducing risks related to supply-demand mismatches, process failures, and logistical issues through real-time data sharing, more accurate demand forecasting, and production automation. However, transport-related risks still face limitations, particularly due to the low digitalization of outsourced services.

Additionally, Maritano et al. (2024) highlight the use of blockchain, RFID, and NFC as effective solutions to combat fraud and counterfeiting in products such as wine, olive oil, and dairy. These technologies ensure traceability and product authenticity, protecting supply chain integrity and strengthening consumer trust.

During the COVID-19 pandemic, blockchain technology proved to be a valuable resource for enhancing the resilience of food supply chains, as noted by Sharma et al. (2022). Its application enabled the tracking of perishable goods, inventory control, and faster decision-making, even in scenarios of severe disruptions.

Furthermore, Luo et al. (2022) emphasize that the gradual integration of technologies such as smart sensors, automation, and digitalization has contributed to reducing losses and waste along the chain, especially for perishable foods. Despite adoption challenges—mainly among small enterprises—these solutions have the potential to increase the sustainability, efficiency, and resilience of FSCs, aligning with global goals such as the Sustainable Development Goals (SDGs).

3.3.4. Present a synthesis of the main risks in food supply chains and strategies to mitigate them

The supply chain is a network of activities, including production, processing, distribution, and consumption, that is highly dependent on partners (actors), support services, and infrastructure (Reddy et al., 2016).

Supply chain management is complex and involves risks that must be managed (Pereira et al., 2020). According to Table 4, fourteen risks were identified and classified: Disruption Risks, Forecast Risks, Intellectual Property Risks, Procurement Risks, Inventory Risks, Capacity Risks, Operational Risks, Demand Risks, Supply Risks, Financial Risks, Environmental and Social Risks, Logistics Risks, Regulatory and Legal Risks, and System Risks.

Natural disasters, terrorist attacks, supplier bankruptcies, and labor disputes cause disruption risks in supply chains, severely impacting companies' operational capacity (Lambert et al., 1998). Due to the complexity and interdependence of supply chains, these events trigger a domino effect (Dolgui et al., 2018). Additionally, such disruptions may involve behavioral uncertainties, fraud risks, information security failures, data loss, human errors, and operational and transactional risks (Alkhudary et al., 2024).

Logistics risks affect production, transportation, and delivery, and worsen in global chains due to port delays and long transit times (Mohezar et al., 2023). Forecast risks refer to the accuracy of demand estimation and impact inventory and production decisions (Kumar et al., 2021; Silva et al., 2023). Demand aggregation and higher responsiveness are recommended (Chopra et al., 2007 since demand variability and changes in consumer habits are ongoing challenges (Dolgui et al., 2018).

Global outsourcing and vertical integration increase intellectual property risks, requiring confidentiality contracts and compliance monitoring (Chopra et al., 2007. Procurement risks involve exchange rate fluctuations, input price variations, and dependence on sole suppliers, which can be mitigated with long-term contracts and financial hedging (Pardaev et al., 2023).

In inventory management, challenges such as obsolescence, holding costs, and uncertainties in supply and demand require inventory balancing and a flexible supply base (Elmsalmi et al., 2021).

Table 4. Risk summary.

No.	Risk Type	Categories	Authors
1	Disruption Risks	Natural Disasters, Terrorist Attacks, Supplier Bankruptcies, Labor Disputes, Pandemics	(Cui & Basnet, 2015; Hachicha & Elmsalmi, 2014 Kuizinaitė et al., 2023; Maritano et al., 2024; Pereira et al., 2020; Sid et al., 2021; Sun et al., 2023)
2	Forecasting Risks	Demand Accuracy	(Ali & Govindan, 2023; Ali & Gurd, 2020; Elmsalmi et al., 2021; Khan et al., 2022a ; Kuizinaitė et al., 2023; Magalhães et al., 2022;
3	Intellectual Property Risks	Confidentiality, Compliance	(Adeseun et al., 2018; Alkhudary et al., 2024; Bogadi et al., 2016; Kuizinaitė et al., 2023; Manning & Soon, 2016; Maritano et al., 2024; Tavakoli Haji Abadi & Avakh Darestani, 2023)
4	Procurement Risks	Exchange Rate Fluctuations, Price Variations, Dependence on Single Suppliers	(Adeseun et al., 2018; Ali et al., 2024; El Ayoubi & Radmehr, 2023; Mohezar et al., 2023; Silva et al., 2023; Soon-Sinclair et al., 2023; Sun et al., 2023; Tavakoli Haji Abadi & Avakh Darestani, 2023)
5	Inventory Risks	Obsolescence, Maintenance Costs, Demand Uncertainty	(Elmsalmi et al., 2021; Kuizinaitė et al., 2023; Luo et al., 2022; Sid et al., 2021; Tavakoli Haji Abadi & Avakh Darestani, 2023)
6	Capacity Risks	Costs, Flexibility	(Ali et al., 2021; Astuti et al., 2014; Diabat et al., 2012; Keramydas et al., 2015; Mohezar et al., 2023; Zavala-Alcívar &Verdecho, 2020)
7	Operational Risks	Equipment Failures, Quality Problems, Operational Performance, System Failures	(Ali & Govindan, 2023; Bogadi et al., 2016; Jurica et al., 2019; Jurica et al., 2021; Manning&Soon,2016;Silvaetal.,2023;Soon-Sinclairetal.,2023; Tavakoli Haji Abadi & Avakh Darestani, 2023; Trmčić et al., 2021)
8	Demand Risks	Demand Variability, Changes in Consumer Preferences, Inaccurate Forecasting	(Ali & Gurd, 2020; Khan et al., 2022a; Kumar et al., 2021; Magalhães et al., 2022; Pardaev et al., 2023)
9	Supply Risks	Supply Failures, Dependence on Single Suppliers	(Ali & Govindan, 2023; Azmi et al., 2021a; Khan et al., 2022b; Kuizinaitė et al., 2023; Silva et al., 2023; Soon-Sinclair et al., 2023; Tavakoli Haji Abadi & Avakh Darestani, 2023)
10	Financial Risks	Financial Solvency of Clients, Price Fluctuations, Exchange Rates	(Ali & Gurd, 2020; Alkhudary et al., 2024; Ghadge et al., 2020; Kuizinaitė et al., 2023; Kumar et al., 2021; Onyeaka et al., 2023; Pardaev et al., 2023)
11	Environmental and Social Risks	Natural Disasters, Sustainability, Food Security, Biological Risks	(Afifa & Santoso, 2022; Alkhudary et al., 2024; Dolgui et al., 2018; Elmsalmi et al., 2021; Luo et al., 2022; Onyeaka et al., 2023; Pardaev et al., 2023; Zhao et al., 2020)
12	Logistics Risks	Transportation, Distribution, Infrastructure	(Elmsalmi et al., 2021; Khan et al., 2022a; Luo et al., 2022; Pardaev et al., 2023; Srivastava et al., 2015; Wahyuni et al., 2021)
13	Regulatory and Legal Risks	Regulatory Changes, Compliance	(Ali & Govindan, 2023; Bogadi et al., 2016; Jurica et al., 2019; Jurica et al., 2021; Manning & Soon, 2016; Maritano et al., 2024; Santeramoetal.,2021;TavakoliHajiAbadi&AvakhDarestani,2023)
14	Systems Risks	IT Failures	(Alkhudary et al., 2024; Ali & Gurd, 2020; Luo et al., 2022; Pardaev et al., 2023; Srivastava et al., 2015; Zhao et al., 2020)

Capacity risks relate to production flexibility in response to demand variations, for which maintenance is recommended (Reddy et al., 2016). Operational risks include production failures such as equipment breakdowns, quality issues, and inefficiencies (Ali & Govindan, 2023; Gouda & Saranga, 2018; Rathore et al., 2017, 2021; Silva et al., 2023; Wahyuni et al., 2021; Zhao et al., 2020), as well as IT system failures (Afifa & Santoso, 2022; Ali & Gurd, 2020).

Demand risks arise from variability and changes in consumer habits, leading to excess or inventory shortage, affecting profitability (Khan et al., 2022a; Magalhães et al., 2022; Mohezar et al., 2023). Poor forecasting increases operational costs and reduces service capability (Ali & Gurd, 2020; Magalhães et al., 2022; Zhao et al., 2020). Supply risks include failures and dependencies in the supplier network, such as delays or bankruptcies, requiring supplier base diversification (Ali & Govindan, 2023; Khan et al., 2022b; Magalhães et al., 2022; Rathore et al., 2017; Zavala-Alcívar & Verdecho, 2020; Wahyuni et al., 2021).

Financial risks are related to economic instability, raw material prices, exchange rate fluctuations, and solvency (Azmi et al., 2021b; Lambert et al., 1998; Nikou & Selamat, 2013; Pereira et al., 2020; Silva et al., 2023).

Environmental and social risks include natural disasters and sustainability issues affecting the supply chain (Ali & Govindan, 2023; Choirun et al., 2020; Davis et al., 2021; Dolgui et al., 2018; Kurniawan et al., 2017; Zhao et al., 2020).

In FSCs, biological, environmental, and demand-related risks stand out. Biological risks include pests, diseases, and contamination (Keramydas et al., 2015; Sharma et al., 2022; Zhao et al., 2020). Extreme weather events like droughts and floods affect food production and quality (Zhao et al., 2020).

Infrastructure failures, such as a lack of cold chains, increase losses and operational costs. Inadequate demand forecasting leads to waste or shortages, which is critical in the food industry due to its perishability (Ali et al., 2021; Soon-Sinclair et al., 2023; Zhao et al., 2020).

The various identified risks exhibit interdependencies, which are illustrated in the diagram shown in Figure 4.

The diagram represents the interdependencies among different types of risks present in FSCs, highlighting how they connect and mutually influence each other.

Forecasting risks, for example, are linked to inventory, demand, capacity, and operational risks, indicating that failures in estimates can directly compromise operational performance. Supply risks, in turn, relate to financial, logistical, and systems risks, demonstrating that instability in one link of the chain can generate impacts across multiple fronts. The connection between operational and regulatory risks also highlights that internal failures can result in legal non-compliance. Table 5 presents a summary of risks, frequency, impact, and mitigation strategies.

Risks in Food Supply Chains (FSCs) rarely occur in isolation; instead, they tend to influence one another, generating cascading effects that amplify negative impacts throughout the chain (Dolgui et al., 2018). This interconnectedness means that the occurrence of one risk can trigger or worsen others, increasing the system's vulnerability systemically.

For example, logistical risks such as port delays or transportation failures increase operational costs and result in product losses, particularly for perishables. This compromises the company's financial stability and demonstrates the direct link between logistical and financial risks (Ali et al., 2019; Zhao et al., 2020). The lack of adequate infrastructure, such as cold chains, intensifies these losses (Luo et al., 2022). At the operational level, equipment failures or production issues can lead to low-quality products, recalls, and damage to reputation (Ali & Govindan, 2023), ultimately negatively affecting demand (Khan et al., 2022a.

Large-scale events, such as pandemics, illustrate the cascading effect of disruption risks. These events simultaneously affect supply, operational costs, and corporate reputation (Sharma et al., 2022). Excessive dependence on a single supplier increases this vulnerability (Kuizinaitė et al., 2023), while regulatory changes or non-compliance can lead to legal sanctions and reputational damage (Manning & Soon, 2016; Maritano et al., 2024).

Considering this complexity, it is crucial to adopt an integrated risk management approach that recognises their interrelationships and cascading effects. The interdependence model proposed in this study (Figure 4) helps visualize how operational failures—such as IT issues, equipment breakdowns, or lack of training—can lead to food contamination, financial losses, and reputational crises (Afifa & Santoso, 2022; Zhao et al., 2020).

In this context, strategies that tackle root causes and interconnected effects are more effective. Technologies such as blockchain and RFID, for instance, not only ensure traceability and combat fraud (Maritano et al., 2024) but also improve supply chain visibility and reduce logistical and operational risks (Sharma et al., 2022). Supplier diversification, highlighted as essential by Khan et al. (2022b) and Pardaev et al. (2023), also lessens exposure to disruption and financial risks.

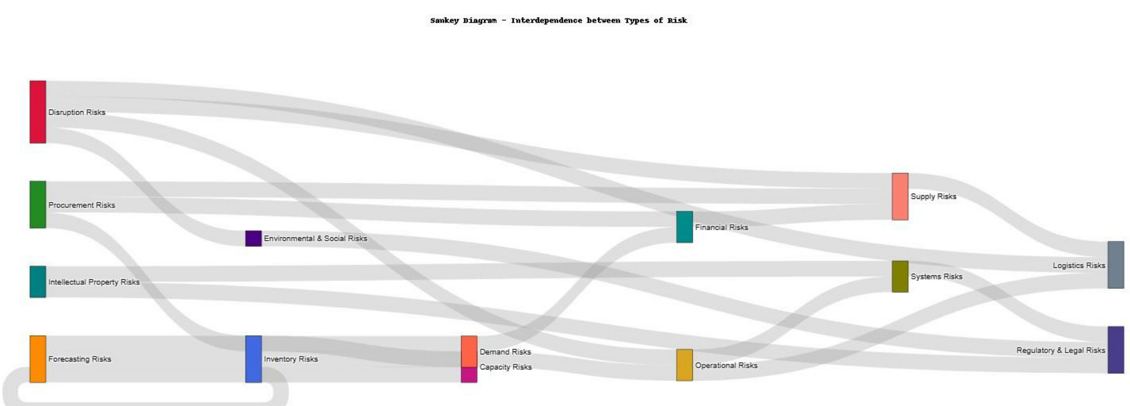

Figure 4. Interdependence between types of risks

Table 5. presents a summary of risks, frequency, impact, and mitigation strategies.

Type of Risk	Frequency	Impact	Mitigation Strategies
Disruption Risks	Very High	Operational capacity, domino effect, behavioral uncertainties, fraud, information security failures, data loss, human errors, operational and transactional risks.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Forecasting Risks	Medium	Inventory and production decisions, increased operational costs, reduced service capacity.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Intellectual Property Risks	Low	Requires confidentiality agreements and compliance monitoring.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Procurement Risks	Low	Exchange rate fluctuations, input price variations, dependence on single suppliers.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Inventory Risks	Low	Obsolescence, holding costs, supply and demand uncertainties.	Safety stock, logistical redundancy, alternative routes, sustainable practices, collaboration with suppliers and customers, automation, training.
Capacity Risks	Low	Production flexibility in response to demand fluctuations.	Safety stock, logistical redundancy, alternative routes, sustainable practices, collaboration with suppliers and customers, automation, training.
Operational Risks	Very High	Equipment failures, quality issues, inefficiencies, IT system failures, food contamination, recalls, substantial losses, poor food quality, customer dissatisfaction, company reputation, financial losses.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Demand Risks	Medium	Overstock or stockouts, profitability impact, increased operational costs, reduced service capacity.	Safety stock, logistical redundancy, alternative routes, sustainable practices, collaboration with suppliers and customers, automation, training.
Supply Risks	Medium	Failures and dependencies in the supplier network, delays or bankruptcies.	Contingency plans for supply disruptions; identification and correction of vulnerabilities.
Financial Risks	High	Economic instability, raw material prices, exchange rate fluctuations, solvency.	Safety stock, logistical redundancy, alternative routes, sustainable practices, collaboration with suppliers and customers, automation, training.
Environmental and Social Risks	High	Natural disasters, sustainability issues, pests, diseases, contamination, extreme weather events affecting food production and quality.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Logistics Risks	Medium	Affects production, transport, and delivery; worsens in global chains due to port delays and long transit times; infrastructure failures (e.g., lack of cold chains) increase losses and operational costs.	Identification and correction of vulnerabilities.
Regulatory and Legal Risks	Medium	Disruptions, penalties, reputational damage, harm to food quality and consumer trust, legal non-compliance.	Contingency plans, supplier diversification and selection, monitoring technologies, preventive maintenance, big data forecasting, audits, tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.
Systems Risks	Medium	IT failures.	IT disaster recovery plans.

Furthermore, practices such as automation, preventive maintenance, and continuous staff training have a positive impact on multiple risks, including operational, demand-related, and reputational risks (Ali et al., 2024; Luo et al., 2022). Thus, the integration of multifunctional strategies contributes to building systemic resilience, avoiding isolated responses and promoting a holistic approach to risk management in FSCs. Another aspect identified in the study concerns how risks have been analyzed over the years, as represented in Figure 5.

Year	2001	2006	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Operational Risks	1	1	1	2	1	3	4	4	5	6	3	2	7	7	17	7	14	1
Environmental and Social Risks		1		2		2	3	4	4	4	3	2	8	5	10	6	12	3
Regulatory and Legal Risks		1	1	1	1	2	3	3	4	4	3	2	6	3	11	5	9	3
Disruption Risks			1	1	1		2	3	3	5	3	2	7	4	11	4	10	2
Supply Risks	1		1		1	1	3	2	2	4	1	2	3	4	11	5	8	1
Financial Risks			1		1	1	4	2	3	1	3	1	2	6	10	1	8	3
Logistics Risks				1	1		2	2	4	2	1	1	3	4	14	5	6	
Demand Risks			1	1		1	3	3	2	1	1	1	1	6	7	4	6	2
Systems Risks	1	1			1	3	3		2	5		1	6	4	3	3	6	1
Capacity Risks			1			2	1	4	1	1	2	1	3	1	7	4	7	
Forecasting Risks				1	1	2	2	3	1		2	1		5	6	2	3	
Inventory Risks						1	1	2		1		1	1	1	4	1	3	
Intellectual Property Risks										1		1	1			1	2	3
Acquisition Risks						1						1					7	

Occurrences per year

Red: Very high frequency; Orange: High frequency; Green: Low frequency; Yellow: Medium frequency

Figure 5. Summary of Risks in Food Supply Chains (FSCs).

The analysis of Figure 5, through the heat map, reveals a growing trend in the number of citations of risks between 2021 and 2023, evidenced by the increase in red and yellow cells, indicating greater recognition and monitoring of these risks. The years 2021 and 2023 stand out due to the high incidence of Operational and Disruption Risks, suggesting a critical period for the supply chain.

Operational Risks were consistently cited, peaking in 2021 (17 citations), as a reflection of events such as pandemics, natural disasters, and economic crises. Disruption risks have grown since 2017, and they are associated with COVID-19, geopolitical conflicts, and technological failures.

Starting in 2018, mentions of Environmental and Social Risks increased, peaking in 2023 and 2024, driven by regulatory requirements and consumer pressures. Financial Risks, although less frequently mentioned, rose in 2021 and 2023, reflecting global economic instabilities. Finally, Intellectual Property and Procurement Risks occasionally appear more relevant in specific contexts.

The temporal analysis highlights structural changes in the types of risks faced by Food Supply Chains (FSCs) over the past fifteen years, delineating three distinct phases: pre-pandemic, pandemic, and post-pandemic.

In the pre-pandemic period (2010–2019), operational and structural risks predominated, particularly in emerging economies. In 2014, for instance, Tunisia faced inventory risks and production capacity risks, associated with storage failures and seasonal production. Between 2012 and 2015, India experienced regulatory risks and logistics risks, reflecting normative changes and limitations in traceability. Meanwhile, developed economies began to exhibit systemic risks: the United Kingdom (2016, 2019) reported system risks and intellectual property risks, while the United States, in 2019, dealt with environmental risks and disruption risks arising from natural disasters and social unrest.

During the pandemic period (2020–2022), risks became more multifaceted and interdependent. In 2020, Australia faced demand forecasting risks in vegetable production, while Indonesia reported institutional sustainability risks. In 2021, India simultaneously faced logistics risks and health risks, due to failures in the public distribution system (PDS). That same year, countries such as the United States, Malaysia, and Australia experienced supply-demand mismatches and labor shortages, characterizing a scenario of widespread disruption. By 2022, secondary risks emerged: India consolidated procurement risks (outsourcing) and governmental risks, while Indonesia registered security risks in a post-pandemic context.

In the post-pandemic period (2023–2024), a strategic reconfiguration of risks is observed. In 2023, the United Kingdom stood out for fraud risks (related to non-audited suppliers) and legal risks (due to reduced inspections). Australia faced financial risks and alignment risks between supply and demand, while Malaysia exhibited a convergence of operational and financial risks, reflecting systemic vulnerabilities linked to high costs and logistical failures.

These patterns demonstrate a transition from localized and operational risks to interconnected and systemic risks, demanding integrated management approaches and public policies aligned with the new global challenges faced by food supply chains. Table 6 summarizes the risk mitigation strategies organized by type.

Risk management in Food Supply Chains (FSCs) requires specific strategies to address the challenges of different types of risks (Table 5). For disruption risks, strategies such as the creation of contingency plans (Hetzenauer et al., 2023; Rathore et al., 2017), supplier diversification (Khan et al., 2022b; Kuizinaitė et al., 2023), and the establishment of alternative logistics routes (Elmsalmi et al., 2021; Zavala-Alcívar & Verdecho, 2020) are essential to deal with unexpected interruptions, such as natural disasters and political issues.

For forecast risks, advanced analytics technologies such as big data (Ali et al., 2024; Ali & Govindan, 2023) and continuous monitoring of consumption trends (Jurica et al., 2021) help improve demand forecasting accuracy. Regarding intellectual property risks, protecting innovations through patents, confidentiality agreements, and tracking technologies such as RFID and blockchain are crucial (Adeseun et al., 2018; Maritano et al., 2024).

Supplier audits, detailed contracts, and the development of local suppliers can mitigate procurement risks (Onyeaka et al., 2023). Efficient inventory management practices, such as adjusted Just-in-Time and tracking technologies, promote optimization and prevent waste (Adeseun et al., 2018; Maritano et al., 2024). For operational risks, sustainable farming practices, preventive maintenance programs, and continuous training in food safety are effective strategies (Ali et al., 2021; Guerin, 2022; Zhao et al., 2020).

Collaboration between suppliers and customers, joint product development, and shared quality management help mitigate demand risks (Afifa & Santoso, 2022; Chen et al., 2013). Regarding financial risks, prudent financial management and using Industry 4.0 technologies strengthen resilience (Ali et al., 2024; Rathore et al., 2017, 2021).

For environmental and social risks, certification programs, reduction of resource consumption, and sustainable practices are essential (Gouda & Saranga, 2018; Zhao et al., 2020). Logistics risks can be minimized through real-time monitoring, preventive maintenance, and correcting vulnerabilities in IT systems (Rathore et al., 2021). Finally, regulatory risks require strict compliance, audits, and sustainable practices to ensure operational reliability and legality (Ali et al., 2019; Silva et al., 2023).

Based on the mapped strategies and risk categories, the Sankey Diagram (Figure 6) illustrates the associations that facilitate the visualization of strategy application according to the nature of the risks (e.g., operational, environmental, logistical). The diagram also distinguishes strategies by their nature (proactive, reactive, or concurrent) and by the level of technological complexity involved.

This representation highlights that the combination of proactive, reactive, and concurrent strategies—when supported by advanced technologies and stakeholder collaboration—contributes to strengthening the resilience and efficiency of food supply chains. Although risk categories are recurrent across the studies analyzed, significant variations are observed regarding geographic contexts and methodological approaches.

Kamble et al. (2022), for instance, emphasize environmental risks in Asian countries, whereas Zhao et al. (2020) ocus on operational risks in North American supply chains. This diversity reflects both the systemic complexity of these chains and the influence of contextual factors. In addition, there is a noticeable gap in the integrated treatment of interdependent risks, such as logistical and inventory-related risks, indicating future opportunities for more systemic and interconnected modeling.

Table 6. Summary of Risk Mitigation Strategies by Type.

Type of Strategy	Main Mitigation Actions	Associated Risks
Proactive	Contingency plans, diversification and selection of suppliers, monitoring technologies, preventive maintenance, forecasts using big data, audits.	Disruption, Supply, Logistics, Operational, Forecasting, Regulatory, Procurement, Systems
	Tracking technologies (RFID, blockchain), automation, HACCP, cybersecurity, certifications, detailed contracts, Just-in-Time, insurance.	Intellectual Property, Capacity, Financial, Environmental and Social, Demand
Proactive and Concurrent	Security stocks, logistical redundancy, alternative routes, sustainable practices, collaboration with suppliers and clients, automation, training.	Inventory, Logistics, Disruption, Operational, Systems, Regulatory, Demand, Financial
Proactive and Reactive	Identification and correction of vulnerabilities.	Logistics
Proactive, Reactive and Concurrent	Contingency plans for supply interruptions; identification and correction of vulnerabilities	Supply, Logistics
Reactive and Concurrent	IT disaster recovery plans.	Systems

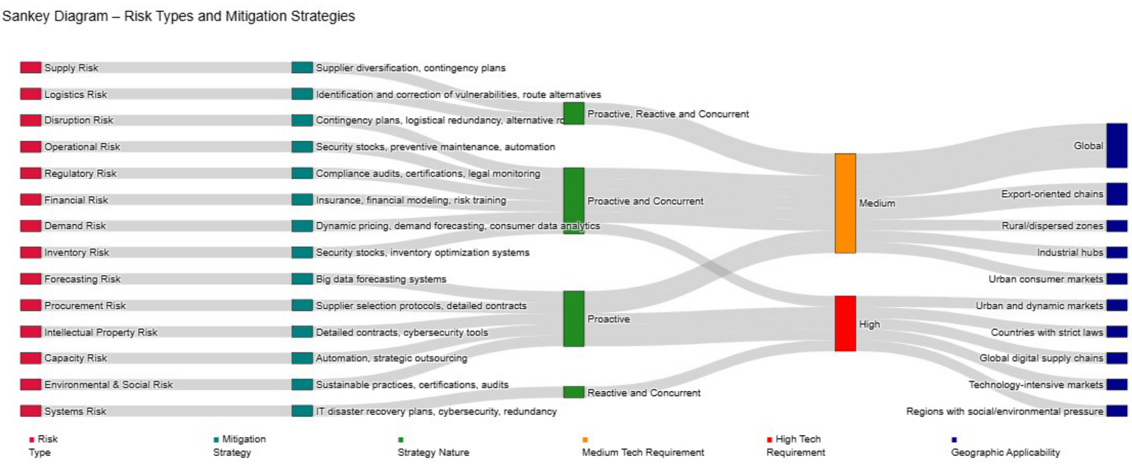

Figure 6. Sankey Diagram of Risks and Strategies.

4. Food supply chains in Brazil

Although this systematic review adopts an international perspective, the Brazilian context presents unique characteristics that require dedicated analysis. Brazil's food supply chains are significantly affected by structural challenges such as logistical inefficiencies, regional climate extremes, technological asymmetries, and the prevalence of informal labor in agricultural operations. These factors amplify risks related to perishability losses, regulatory delays, and food safety concerns.

Studies such as Pereira et al. (2020) highlight recurring issues in Brazilian agri-food chains, including post-harvest losses, storage bottlenecks, and communication failures between supply chain actors, especially perishable products. Additionally, the country's large territorial size and heterogeneous production matrix increase the complexity of managing risks, making adopting strategies tailored by region and product type necessary.

Brazil's central role in global food supply makes the discussion of risks in food supply chains (FSCs) highly relevant. In 2024, agribusiness accounted for 48.6% of Brazilian exports in the first semester, according to the Carta de Conjuntura from IPEA (Instituto de Pesquisa Econômica Aplicada, 2024), in addition to recording a trade surplus and maintaing a strong international presence. Official data also indicate significant volumes of agricultural production and exports throughout 2024 (Instituto Brasileiro de Geografia e Estatística, 2025), reinforcing the country's dependence on logistics flows, sanitary standards, and stable macroeconomic conditions. In this context, episodes such as avian influenza (H5N1)—with official reports confirming an outbreak in captive birds at the Bioparque in Rio de Janeiro in July 2025 (Brasil, 2025) —and atypical bovine spongiform encephalopathy (BSE/mad cow disease) cases reported by the Ministry of Agriculture in 2023 (Brasil, 2023) illustrate how biological risks can trigger sanitary barriers and affect markets. At the same time, exchange rate volatility, as documented by the Central Bank (Banco Central do Brasil, 2025), increases price and margin uncertainties, impacting contracts, hedging strategies, and purchasing and sales decisions throughout the supply chain.

Besides these examples, this article categorises 14 types of risk that appear in food supply chains and help define the Brazilian context: disruptions, forecasting failures, intellectual property, procurement (including currency exchange), inventory, capacity, operational, demand, supply, financial, environmental and social, logistical, regulatory/legal, and systems risks. These risks are interconnected and can cause ripple effects—for example, the depreciation of the Brazilian real or price shocks heighten procurement/financial risks, which then affect inventory, logistics, and operations; similarly, sanitary events (avian flu/BSE) trigger regulatory and logistical risks, directly impacting quality, costs, and the continuity of supply.

Despite these challenges, few studies directly focus on the Brazilian reality. Moreover, national literature remains scarce regarding technological and quantitative approaches to risk mitigation. Therefore, future research should prioritize empirical studies that explore and address these regional particularities. The Brazilian agri-food sector represents a promising field for applied interventions and policy innovation to enhance resilience in local supply chains.

5. Conclusion

This systematic literature review contributes to advancing the knowledge on risks in Food Supply Chains (FSCs) and the strategies used to mitigate them. The study identified and categorized 14 main types of risks and mapped a broad and diverse set of mitigation strategies. From a theoretical standpoint, the results provide a structured foundation for developing risk management models and decision-support tools, which are particularly relevant in data-scarce contexts such as Brazil. From a practical perspective, the study offers guidance for managers and policymakers, highlighting the importance of adopting digital technologies (such as IoT, blockchain, and AI), fostering interorganizational collaboration, and implementing hybrid strategies to strengthen the resilience of FSCs.

Despite these contributions, some limitations should be acknowledged. The main limitation lies in the exclusive reliance on secondary data from scientific literature, which may limit the generalizability of the findings, especially in specific geographic and socioeconomic contexts. The heterogeneity of the included studies—with varying methodologies and focuses (types of food, regions, qualitative and quantitative approaches)—also poses challenges for direct comparison of results. Moreover, although a section was dedicated to the Brazilian context, the scarcity of empirical studies focused on the specificities of FSCs in Brazil limits the direct applicability of some of the strategies identified.

The dominance of international studies further highlights the need for adaptations to Brazil's logistical, regulatory, and social contexts. Lastly, the continuous evolution of risks—such as those concerning cybersecurity, climate change, and pandemics—requires regular updates to the literature and flexible research approaches. Based on the identified gaps, the following research agenda is proposed:

1. Empirical and context-specific studies in Brazil: Conduct field research in key segments (such as fruits, grains, and dairy) across different regions, focusing on the country's operational and regulatory particularities;

2. Longitudinal analyses: Monitor the evolution of risks and assess the effectiveness of mitigation strategies over time, contributing to a more dynamic understanding of resilience in FSCs;

3. Application of emerging technologies: Investigate how solutions based on AI, machine learning, and big data analytics can forecast and mitigate risks, especially in highly variable environments;

4. Exploration of under-researched risks: Expand investigations into less-explored risks, such as cybersecurity, informality in operations, and the impacts of climate variability;

5. Modeling of risk interdependencies: Develop causal mapping techniques to capture cascading effects among different types of risks and propose integrated mitigation strategies;

6. Intersection between sustainability and resilience: Analyze how sustainable practices can simultaneously reduce risks and enhance FSCs' responsiveness to diverse shocks;

7. Challenges and opportunities for integration in Brazil: Consider structural barriers, such as poor logistics and technological disparities among producers, while also exploring the transformative potential of digital technologies and collaborative initiatives.

By addressing these points, future research can contribute to strengthening FSCs not only in terms of operational efficiency but also regarding food security, sustainability, and adaptability to increasingly complex risk scenarios.

Data availability

No research data was used.

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Supplementary Material

Supplementary material accompanies this paper.

Supplementary Material – Search Strategy and List of Articles Included.

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