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AGRO-FOOD SUPPLY CHAIN RISK ASSESSMENT: A REVIEW BASED ON TECHNIQUE AND APPROACH

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ABSTRACT
Risk assessment in agro-food supply chains is crucial in managing the complexity and uncertainty associated with food product production, distribution, and consumption. This study aims to classify risks and mapping techniques or approaches used in risk assessment of agro-food product supply chains. Mapping technique or approaches to risk assessment of agro-food supply chains was carried out based on the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework, which consists of several stages of identification, screening eligibility, and inclusion, resulting in a total of 72 relevant journal articles. They were selected from 58 different journals with high-impact factors and rankings. The literature review results show that agro-food's supply chain risk classification has much to do with risk assessment: macro-level risk, operational risk outside the company, and internal risk. Furthermore, the most studied agro-food products are general food (44%), horticultural products (28%), meat products (11%), dairy products (10%), fishery products (6%) and bread products (1%). The techniques and approaches most widely used in assessing the risk of the agro-food supply chain are semi-quantitative (49.3%), quantitative (31.5%), mixed (12.3%), and qualitative (6.9%). A better knowledge of the topic being addressed in the research community is sped up by identifying these techniques and approaches since the literature on supply chain risk management for agro-food is voluminous, complicated, and challenging to grasp.
Keywords : *Supply Chain Risk, Risk Assessment, Agro-Food, Technique and Approaches, Literature Review*

1. Introduction

Supply chain management has a vital role in the agro-food industry to make sure the smooth flow of goods or food delivered to consumers at the right amount and in the right time; because it is the main food provider for the global population, agro-food is very important for the global economy (Sufiyan et al., 2019). Over the past few decades, practitioners and researchers have paid close attention to this type of supply chain management (Nakandala et al., 2017; Onggo et al., 2019). An agro-food supply chain (AFSC) is a commercial network that deals with production, post-harvest, packaging, processing, shipment, and pre- and post-consumption (Behzadi et al., 2018a). The agro-food chain is a sophisticated system that transports agricultural goods from the first phases of production to the point of consumption (Zhao et al., 2019). According to (Barbosa, 2021), the agro-food supply chain suffers continual difficulties as a result of variables such as fluctuating food prices, climate-controlled unpredictability, food waste, concerns with nutrition and food safety, and governance problems. Although the agro-food supply chain has similarities with the supply chain for manufactured goods, the agro-food supply chain has a unique attribute, namely perishable goods (Jonkman et al., 2019), which makes managing the agro-food supply chain more challenging and carries risks in every activity of supply chain (Onggo et al., 2019; Singh et al., 2018).

In today's business environment, risks and uncertainties inevitably occur (Tran et al., 2018). One of the critical issues of agri-food supply chain management is managing uncertainty and risks such as microbial contamination or chemicals such as dangerous heavy metals (Paillin et al., 2022). Therefore, FAO considers that risks in food supply chains are significant, so (OECD-FAO, 2016) has published responsible agricultural supply chain guidelines for risk categorization of food and food companies to improve food safety by strengthening food inspection systems. Risk is the chance of unwanted events or the unpredictability of future outcomes. Risk will always exist and cannot be avoided, but effective risk management may reduce its influence on supply chain performance (D. B. Paillin & Tupan, 2021). The fundamental principles of risk management may be used as usual, beginning with an awareness of the risk management cycle since risk management in agro-food supply chain management is identical to risk management in general. Risk management aims to support decision-making by assisting in identifying, classifying, measuring, managing, and controlling risks (Ennouri, 2013). Several studies have been conducted, showing diversity of methods or approaches in the identification and assessment of risks in food supply chains. Methods for assessing supply chain risk for three risk variables have been developed in the soft drink sector ((Raihan et al., 2022); Supply chain risk assessment (SCRA) of the vulnerability of certified coconut sugar in Kulon Progo Regency - Special Region of Yogyakarta on the aspect of operational risk has been analyzed (Sari et al., 2021); Development of a supply chain risk assessment framework for canned tuna products by looking at operational risk aspects (Sumrit & Srisawad, 2022). Combining several methods for evaluating supply chain risk for fresh agricultural products has been funded by (Wang & Hao, 2016).

Studies on review literature related to agro-food supply chains have been carried out, including (Behzadi et al., 2018a; Luo et al., 2018; Rao et al., 2021; Imbiri et al., 2021; and Yadav et al., 2022). A review of quantitative decision models focusing on food security in assessing and managing risks in agricultural supply chains has been analyzed by (Behzadi et al., 2018a). (Luo et al., 2018) Identified six clusters for agri-food supply chain management research through bibliometric analysis, where the third Cluster focused on Agri-food Supply chain traceability modeling, risk management, and optimization, with studies adopting operational research methods and models mathematics. Review European private food safety standards significantly impact the structure of global supply chains and food safety management systems analyzed by (Rao et al., 2021). A systematic literature review was carried out to develop a new taxonomy for categorizing risks in agribusiness supply chain risk management (Imbiri et al., 2021). (Yadav et al., 2022) Conducted a systematic literature review to identify various challenges in the agri-food supply chain and reviewed the contribution of research in designing agro-food supply chain networks. Apart from the many reviews of previous research to the best of our knowledge, a comprehensive review of Agri-food Supply Chain Risk Assessment (AFSCRA) research is still rare and needs further development; no previous research has discussed in depth the use of methods or approaches that can be used to assess risk supply chain. However, issues surrounding food security and related risks are critical. Choosing the correct method and approach will lead to the right risk management decisions.

Therefore, this research aims to conduct a systematic literature review to identify and classify the development of methods or approaches to assessing supply chain risks, specifically for agro-food products that are easily damaged, have short shelf life, and are easily contaminated. This research also maps the aspects of identifying risks in the agro-food supply chain, which will be used in the management stages.

The large body of literature on supply chain risk management in the agri-food sector is extensive, complex, and often challenging to understand, requiring the identification of precise methods and approaches, especially in supply chain risk assessment. We expect to provide a comprehensive overview covering the various aspects of developing and implementing a risk assessment and explaining the interactions between risk assessments and other related activities within a supply chain risk management framework. Following, we propose a classification framework to improve understanding in this area and offer perspectives for future research.

2. Methodology

Systematic literature reviews (SLR) manage the breadth of knowledge relating to a particular academic inquiry and assist researchers in mapping and evaluating existing intellectual domains, thereby framing a path for the further advancement of existing knowledge

(Imbiri et al., 2021). Research literature reviews are intended to inform readers on how to find, evaluate, and analyze research literature to discover what is known about a topic. The method used refers to (Bintara et al., 2023) with the stages of determining the selection of the journal, time horizon, selection of article and analysis.

Journal Selection

Journal sources are taken from several primary and reputable publishers including science direct, IEEE, emerald, taylor and francis, springer, and those entered and indexed by Scopus to collect high-quality articles (with quartiles Q4 to Q1) related to chain risk assessment supply of agro-food. Scopus was chosen as the basis for searching documents. After all, Scopus is a website with the world's most extensive database of peer-reviewed literature because Scopus has advantages and makes document searching simpler than other indexing websites (Fingerman, 2006).

Scopus also maintains a document database of various topics and types. Keywords must be chosen to get related papers. Searching for papers that meet specified criteria is how filtering is done. The search parameters include the document, affiliation, author, and advanced categories. Several location possibilities exist, including the complete document, titles, abstracts, or keywords. They can be combined and varied to make it simpler for alternatives to search for different types of information as needed. In order to obtain information on the development of AFSCRM, the first search was conducted by entering the needed general keywords. A further search was carried out with various desired criteria with keywords such as " agro-food supply chain risk management ", " agro-food supply chain risk assessment ", " risk assessment in agroindustry supply chain ", " food industry ", and " food product ". In addition, inclusion criteria were also set to limit the types of journal articles obtained, such as 1. Articles focused only on discussing methods and approaches to AFSCRA; 2. Document type: journal articles that have undergone a strict peer-review process; 3. type of study: empirical; and 4. Language: English.

Time Horizon

This study's time horizon for selecting journal articles was taken from 2012 to April 2023. This period was chosen because it was used to study trends and analyze the development of methods used, especially in the field of AFSCRA. The range of article selection from 2012 to 2023 reveals the evolution in research on risk assessment of agro-food supply chains. In 2012, initial studies may focus on the basic concepts and methodology of risk assessment. As time goes by, research tends to develop in a more practical and applicable direction. More recent studies may have explored using information technology, data analysis, and predictive models to more effectively identify and manage risks in agro-food supply chains. By tracking articles from this period, researchers can understand current trends and identify future research needs to improve the sustainability and resilience of agro-food supply chains.

Article Selection

Here, the SLR carried out is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) framework, which consists of several stages, as shown in Figure 1. The PRISMA framework was adopted because it allows researchers to conduct systematic reviews and assess, collect, and analyze critical research, studies, and existing literature (Bintara et al., 2023).

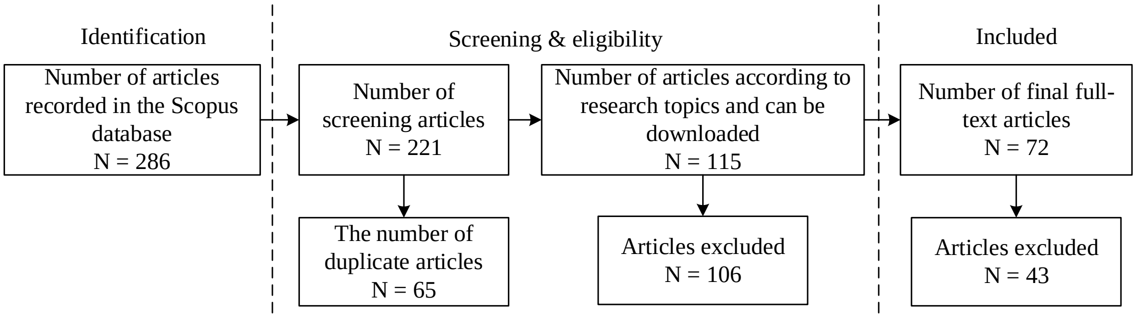

Fig. 1. Article Selection Process

Stage 1 emphasizes identification; as explained above, the inclusion criteria for article selection are articles that focus on discussing methods and approaches to AFSCRA, document type, namely journal articles that have undergone a rigorous peer-review process and full text. The studies are available, systematic, and empirical; the articles must be in English and have a predetermined database. Data collection includes titles, abstracts, years, keywords, publishers, and keywords stored in a Comma Separated Values (CSV) file, exported to MS Excel, and then processed according to research needs. At this stage, the data collected was 286 articles from various journals and publishers. Stage 2 screening and eligibility, namely the collection and independent review of all document reference data in the previous stage. Of the 286 articles, 65 articles were deleted due to duplicate articles; then, the remaining articles focused on eligibility, where articles were selected that met requirements such as the availability of full text and could be accessed, consideration of the suitability of the title, keywords, abstract and contents of the paper. Therefore, articles that are not suitable can be removed, leaving 115 articles. Meanwhile, stage 3 emphasizes inclusion, where the selection process allows the identification of articles in the review. At this stage, 72 articles were helpful in the systematic review of this research, and 43 articles were excluded because they were unsuitable and irrelevant to the topic under study.

Analysis

In this study, three analyses were used: descriptive analysis, AFSCRA definitions and risk categories in SCRA, and analysis of the techniques or approaches used in selected articles in the systematic literature review process. The descriptive analysis includes categories describing the article's characteristics, such as the year of publication, publisher (journal, database with impact factor examination on Scimago), and the agro-food product category being studied. Furthermore, AFSCRA is defined and categorized as risk dimensions or aspects assessed in the AFSC. Analyzing techniques and approaches in AFSCRA includes the techniques or approaches used in the AFSCRA assessment

3. Result and Discussion

Descriptive Analysis

The chosen papers were divided into categories for the descriptive analysis according to the year of publication, ranking and impact variables, and the agro-food category. Figure 2 shows the number of publications according to the year of research. AFSCRA research tends to be small and stable from 2012 to 2014 before rising significantly in 2017 and dropping slightly in two years. However, in the last five years until 2022, AFSCRA research has experienced a significant increase, so overall, AFSCRA research shows an increasing trend from year to year.

The publications that have been examined have been published in 58 journals, all of which are Scopus-indexed, or they have been archived in the databases of reputable publishers, including springer, elsevier, wiley-blackwell, taylor & francis, emerald, and MDPI. Forty-one articles (56.94%) have been published in journals with a Q1 rating that has an impact factor ranging from 0.636 to 2.81; fourteen articles (19.44%) have been published in journals with a Q2 rating that has an impact factor ranging from 0.33 to 2.41; fourteen articles (19.44%) have been published in journals with a Q3 rating that has an impact factor ranging from 0.16 to 0.33; and three articles (4.17%) have been published in journals with a Q4 rating. Table 1 shows the title, impact factor, and rating of each journal that published at least two of the articles for this article review

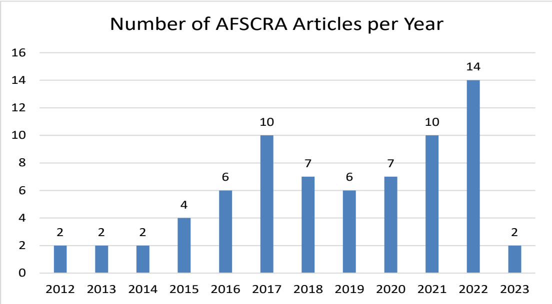

Fig. 2. Number of articles reviewed from 2012-April 2023.

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Table 1 - Title, Impact Factor, The Rank Of Journals, And Number Of Reviewed Articles Equal To Or Greater Than Two

Journal Title	**Impact Factor***	**Rank***	**Number of Articles**
International Journal of Production Research	2,78	Q1	4
International Journal of Production Economics	2,81	Q1	2
Supply Chain Management	2,39	Q1	2
Production Planning and Control	1,66	Q1	2
International Journal of Logistics Management	1,5	Q1	2
Management Decision	1,16	Q1	2
Food Control	1,08	Q1	2
Risk Analysis	0,92	Q1	2
PLoS ONE	0,85	Q1	2
International Journal of Environmental Research and Public Health	0,81	Q1	2
Journal of Islamic Marketing	0,55	Q2	2
Acta Logistica	0,24	Q3	2
Industrial Engineering and Management Systems	0,16	Q3	2

Note: * Scimago Journal & Country Rank April 2023

Furthermore, Figure 3 illustrates the categories of agro-food products that are the object of research. As we can see, most research objects or studies are general food (palm oil, coconut sugar, fresh food, pasta, etc.), amounting to 44% of the articles reviewed later. Horticultural products (mangoes, grapes, rice, etc.) also became the object of study, namely, 28% of the articles reviewed. The category of dairy products (dairy, cheese, milk) and meat products (beef, pork, poultry, etc.) is 10% and 11% of the number of articles reviewed, while the minor object of study is fishery products (tuna, seaweed, and mackerel) and beverage products by 6% and 1%.

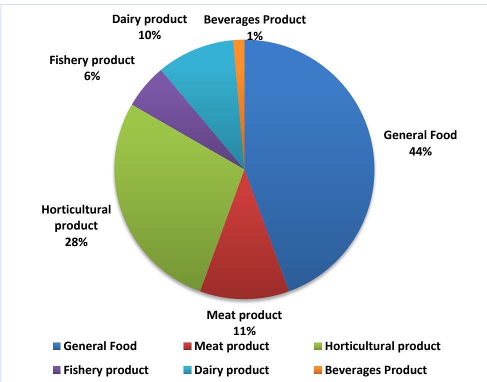

Fig. 3. Agro-Food Product Categories

In recent years, there has been a significant increase in research related to agro-food supply chain risks. The shift in research focus from simply identifying risks to placing more emphasis on understanding the complex dynamics in these supply chains has become a significant trend. Recent studies highlight various aspects, from food security to the impact of climate change, demographic changes, and the latest technology in improving supply chain efficiency and security. However, this increased attention also raises several challenges. One is the increasing complexity of modelling and predicting risks associated with agro-food supply chains. Factors such as seasonal variations, unpredictable climate changes, and changing regulatory policies add complexity to risk analysis. Another challenge is the heavy reliance on accurate and real-time data. In agro-food supply chains, where weather conditions or policy changes can directly impact production and distribution, fast and accurate access to data is critical to managing risk effectively. Apart from that, another main challenge is integration between the various parties involved in the supply chain. Since the agro-food supply chain involves several entities ranging from farmers, producers, and distributors to retailers, effective coordination and collaboration are essential to ensure overall efficiency and safety.

AFSCRA definition, and AFSC risk categories

Classification of food products can be categorized into seven categories as follows: (1) Horticultural products (generally fruit, grape vines, mango, apple, fresh-cut lettuce, roses, common flowers); (2) Meat products (general meat, pork, poultry, beef,); (3) Dairy products (general, milk, cheese); (4) Fishery products (general seafood, tuna, seaweed, crabs, smoked fish); (5) Bakery products (general bakery, bread); (6) Beverages (general beverages, wine, beer, soft drink); and (7) Other foods (eggs, sushi, pasta, coffee, olive oil) (Costa et al., 2013). The agro-food supply chain is divided into two groups, according to (Taşkıner & Bilgen, 2021), including the supply chain for fresh and non-perishable agro-foods. Food supply chains differ from other chains in several ways, including: 1. Food supply chains are comparatively long and are affected by intricate factors; 2. production, storage, and delivery times require strict oversight; and 3. Food supply chains have comparatively high similarities and interactions (Guan et al., 2011). AFSC often faces risks related to perishability, product deterioration and waste and others. After they are produced, agro-food products in the supply chain experience declining quality and value (Chen et al., 2020); therefore, as a risk in the food supply chain, food quality and safety are given much attention by the community (Alabi & Ngwenyama, 2023). Assessment of risks, management of food safety and quality, traceability, and sustainability must all be included in the evaluation of the food supply chain.

Implementing SCRM actions involves three primary phases: before, during, and after the risk. Supply chain managers may adopt SCRM in one, two, or all three stages, but the success of the SCRM solution for each step is always based on how well the risk assessment was conducted. The potential for failures, operational problems, credit loss, and economic losses stemming from various unanticipated causes while each nodal business along the food supply chain is in operation is what is referred to as an AFSC risk (Zhao et al., 2020). Risk is measured by researchers and industry practitioners using probability, impact, detectability, recovery time, or the relationship between risks. (Garvey et al., 2015; Ghadge et al., 2012; Giannakis & Louis, 2011) use the same terms or terminology in risk assessment, measurement, and quantification. The assessment of supply chain risks is an important phase in the SCRM process; we define AFSCRA as “activity involves qualitatively or quantitatively judging, analyzing, calculating, quantifying, measuring, evaluating, and modelling individual indicators, aggregated scores, or overall levels of risks in supply chains for agro-food product to develop sound fundamentals for risk mitigation and other management decisions”.

Categorizing risks in the supply chain, agricultural supply chain, and agribusiness food chain may be used to classify risks in AFSC. The reason is that agriculture supply and food chain construction are inextricably linked. The food product supply chain is a network of enterprises that participate in a variety of processes and activities in order to fulfil and satisfy client needs (Bhagat & Dhar, 2011). In this research, we attempted to categorize the risk for AFSCR, which was taken from (Manuj & Mentzer, 2008) namely (figure 4): 1. internal risk; 2. operational risk outside the company and; 3. macro-level risk.

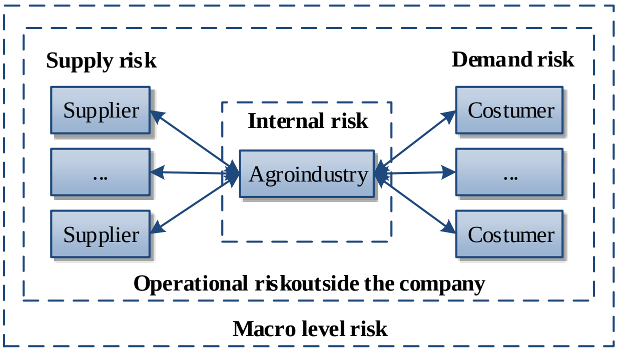

Fig. 4. AFSCR category

According to (Christopher & Peck, 2004), internal risk includes risks within the company, among them process and control risk. The possibility of an unforeseen event disrupting the regular flow of goods, services, and information in the supply chain puts the company at risk for an external operational risk, which could have negative repercussions for supply chain participants and make it impossible to meet customer demands (Zsidisin, 2003). Supply and demand risks are mainly included in operational risks outside the company, while macro-level risks are brought on by traumatic events like wars and natural disasters. Furthermore, several studies on AFSCRA that have been identified and classified as risk are displayed in Table 2.

Table 2 - Risk in agro-food supply chain

Risk category	Reference
Internal risk (Manufactring risk, business risk, production risk, cultural risk, excessive inventory, quality risk, mitigation and contogency risk)	(Mulyati & Geldermann, 2017);(Y. Wang & Hao, 2016); (Leat & Revoredo-Giha, 2013); (Nakandala et al., 2017); (Diabat et al., 2012); (S. Khan et al., 2022); (Tavakoli & Darestan, 2023); (Baihaqi et al., 2021); (Rosales et al., 2020); (Raihan et al., 2022); (Pereira et al., 2020); (Prakash et al., 2017); (Yu & Huatuco, 2016); (Bai et al., 2018); (Jianying et al., 2021); (Azmi et al., 2021)
Operational risk external to the firm (Supply risk, storage and transport risk, distribution risk, raw material supply risk, supply quality risk, supplier delivery delay, demand risk, customer tastes changes, environmental risk, business risk)	(Cui & Basnet, 2015); (Nakandala et al., 2017); (Pereira et al., 2020); (Diabat et al., 2012); (Prakash et al., 2017); (Enyinda & Mbah, 2017); (S. Khan et al., 2022); (Nguyen, 2022); (Rathore et al., 2017); (Tavakoli & Darestan, 2023)(Yu & Huatuco, 2016); (Raihan et al., 2022); (Rosales et al., 2020); (Leat & Revoredo-Giha, 2013); (Bai et al., 2018)
Macro-level risk (Weather/natural disasters, Political (POL), government policy, labour strikes, diseases)	(Diabat et al., 2012); (Nakandala et al., 2017); (Azizsafaei et al., 2022); (Raihan et al., 2022); (Enyinda & Mbah, 2017); (Pereira et al., 2020); (Prakash et al., 2017); (Enyinda & Mbah, 2017); (Nguyen, 2022); (Anugerah et al., 2022)

Techniques to assess risk in the agro-food supply chain

The 72 articles selected for review used various methods and approaches to assess risk in AFSC. The methods used were then grouped into four groups, namely qualitative (6.9%), semi-quantitative (49.3%), quantitative (31.5%), and mixed (12.3%) methods. Table 3 below provides further information.

Table 3 -Technique and approach of AFSCRA

Group Methods	Technique or Approaches	Reference
Qualitative	Exploratory study	(Assefa et al., 2017; Cui & Basnet, 2015; Leat & Revoredo-Giha, 2013; Pereira et al., 2020)
	Depth interviews	(Baron & Frattaroli, 2016)
Semi-Quantitative		
Generic semi-quantitatif	Risk matrix by multiplying probability and impact	(Mulyati & Geldermann, 2017)
	Risk Ranking	(Santeramo et al., 2021)
Single MCDM	ISM	(Diabat et al., 2012; Prakash et al., 2017; Srivastava et al., 2015)
	AHP	(Enyinda & Mbah, 2017; W. Khan et al., 2022)

Group Methods	Technique or Approaches	Reference
	TOPSIS	(Y. Wang & Hao, 2016)
	Fuzzy AHP	(S. Khan et al., 2022; X. Wang et al., 2012)
	Spherical fuzzy sets - AHP	(Nguyen, 2022)
	Fuzzy ISM	(Chaudhuri et al., 2016)
	DEMATEL	(Benabdallah et al., 2022; Mithun Ali et al., 2019)
Multi MCDM	Grey AHP-Grey TOPSIS	(Rathore et al., 2017)
	ELECTRE -AHP	(Duret et al., 2019)
	AHP and entropy weight method	(Shen & Liao, 2022)
	PF-MEREC-RS-GLDS	(Zhai et al., 2022)
	Fuzzy FMEA- VIKOR	(Sumrit & Srisawad, 2022)
	FMEA-AHP	(Anugerah et al., 2022)
	Fuzzy BWM - Fuzzy WASPAS	(Tavakoli & Darestan, 2023)
FMEA and Modified Model	House of Risk	(Kasemset et al., 2014; Maman et al., 2018; D. Paillin et al., 2022)
	Fuzzy House of Risk	(Asrol et al., 2021)
	FMEA	(Sari et al., 2021; Suryaningrat et al., 2021; Yu & Huatuco, 2016)
	Fuzzy FMEA	(Baihaqi et al., 2021)
Intelligent Technique	IoT based on OWA Operator	(Yan et al., 2017)
	TAMSAT-ALERT (Agricultural Decision support system)	(Asfaw et al., 2018)
	Support Vector Machine	(Zhang et al., 2020)
	Backpropagation and particle swarm optimization algorithm	(Jianying et al., 2021)
Others	RASFF	(Robson et al., 2021)
Quantitative		
Mathematic model	Fuzzy supply-driven input-output	(Brosas et al., 2017)
	A multi-commodity multi-period optimisation	(Behzadi et al., 2018b)
Statistical analysis	Regression	(Welburn et al., 2016)
	Ordinary least square regression model	(Nyamah et al., 2017)
	Principal component analysis	(Sun et al., 2020; Tian & Li, 2019)
	Basic descriptive statistics	(Heinzova et al., 2022)
	Factor analysis	(Rosales et al., 2020)
	Exploratory factor analysis	(Azmi et al., 2021)
Statistical modelling	Bayesian Network	(Cao et al., 2019; Qazi et al., 2018; Yang & Liu, 2018)
	Structural equation model	(Kim, 2013; Rath et al., 2022)
Spatial modelling	CanGRASP	(Leblanc et al., 2015)
Simulation	Agent-based modelling	(Ge et al., 2015; Hidayat & Marimin, 2014)
	Coloured Petri-Net Simulation	(L. Liu et al., 2018)
	System dynamic	(Azizsafaei et al., 2022)
Others	Quantitative microbial risk assessments	(Brusa et al., 2020; Horr & Pradhan, 2020; Pang et al., 2017; Stefanou et al., 2022)
Mixed	Fuzzy DIIM	(Niknejad & Petrovic, 2016)
	Fuzzy logic and hierarchical holographic modelling	(Nakandala et al., 2017)
	FCEM and FMECA	(Bai et al., 2018)
	Total ISM and fuzzy MICMAC	(Zhao et al., 2020)
	ISM and MICMAC	(Ramos et al., 2021)
	Modified hybrid binary particle swarm optimization algorithm	(Z. Liu et al., 2021)
	AHP–OWA and conditional value-at-risk	(Yan et al., 2019)
	Fuzzy AHP-FCEM	(Raihan et al., 2022)
	Fuzzy multiconnection theory and AHP	(Li et al., 2023)
	Hidden Markov model based on grey relational analysis	(Han et al., 2019)

Note: Abbreviations: Interpretive structural modelling (ISM); Analytic hierarchy process (AHP); Technique for order preferences by similarity to ideal Solution (TOPSIS); Decision-making, trial and evaluation laboratory (DEMATEL); Elimination et choix traduisant la realité and analytical hierarchy process (ELECTRE); Pythagorean fuzzy sets (PF); the method for removal effects of criteria (MEREC); the rank-sum and the gained and Lost dominance score (RS-GLDS); Filure mode and effect analysis (FMEA); Vsekriterijumska optimizacija ikompromisno resenje (VIKOR); Best-Worst Method (BWM); Weighted aggregated sum product assessment (WASPAS); Fuzzy Inference System (FIS); Fuzzy Associative Memories (FAMs); Internet of Things (IoT); Ordered weighted averaging (OWA); Rapid Alert System for Food and Feed (RASFF); Canadian GIS-based Risk Assessment, Simulation and Planning for food safety (CanGRASP); Dynamic Inoperability Input Output Model (DIIM); Fuzzy comprehensive evaluation model (FCEM); failure mode, effects, and criticality analysis (FMECA); Matrix of cross-impact multiplication applied to classification (MICMAC)

Qualitative

Making formal assessments of risk indicators, such as consequence and likelihood, using verbal scales rather than purely numerical values is what is required in a qualitative risk assessment. It is a direct and rapid evaluation approach usually used when resources, the correct data, or time are limited (Tran et al., 2018).

The depth interviews and exploratory study approach were carried out with experts to obtain an assessment of supply chain critical risk factors for fast food, pork, manganese, and poultry products (Assefa et al., 2017; Cui & Basnet, 2015; Leat & Revoredo-Giha, 2013; Pereira et al., 2020) (Baron & Frattaroli, 2016).

A qualitative supply chain risk assessment approach offers the advantage of understanding complex, non-directly measurable contexts. Narrative and descriptive analysis in a qualitative approach makes it possible to identify risk factors that may be missed in a quantitative approach. However, its main drawback is its inherent subjectivity. Variability between individual assessments can lead to inconsistent results and a lack of objectivity in risk mapping (Abdel-Basset et al., 2019).

Semi-Quantitative

Approaches to assess both quantitative and qualitative risks are referred to as the semi-quantitative approach, which is based on a quantitative technique. The AFSCRA identification results for the semi-quantitative method were divided into six sub-groups: generic semi-quantitative, Single MCDM, Multi MCDM, FMEA and Modified Model, Intelligent Technique, and others. The most frequently used sub-group, “single MCDM”, is the ISM method in assessing priority risk factors in supply chains of fresh food and dairy product (Diabat et al., 2012; Prakash et al., 2017; Srivastava et al., 2015). Furthermore, the AHP technique was used by (Enyinda & Mbah, 2017; W. Khan et al., 2022) in finding the weight of priority risk factors in the agro-food supply chain, then (S. Khan et al., 2022; X. Wang et al., 2012) used fuzzy AHP by converting pairwise comparison matrix values to triangular fuzzy number (TFN) values for assessing risk aspects in the supply chain of food product.

The next most frequently used semi-quantitative sub-group is the "FMEA and Modified Model", including the FMEA method for assessing supply chain risks for dairy products in China, Edamame products in Japan and Coconut sugar products in Jogjakarta Province in Indonesia (Sari et al., 2021; Suryaningrat et al., 2021; Yu & Huatuco, 2016). The HoR technique, which is a development of the FMEA and QFD methods, is also used by (Kasemset et al., 2014; Maman et al., 2018; D. Paillin et al., 2022) in assessing risk factors in the supply chain of pork and red meat products by looking at the highest aggregate risk potential (ARP) value for choose priority risks. (Kasemset et al., 2014; Maman et al., 2018; D. Paillin et al., 2022) also used this method to assess risk factors in the dimensions of sustainability for tuna supply chains. The following semi-quantitative subgroups that are widely used are "multi MCDM" and "intelligent technique" in assessing agro-food supply chain risks, including the Gray AHP-Grey TOPSIS technique used by(Rathore et al., 2017) , the ELECTRE technique - AHP is used by (Duret et al., 2019) to evaluate the risk of cold food supply chains, the Support Vector Machine technique is used to assess priority risks in the fresh food supply chain (Zhang et al., 2020), and the BP-PSO technique is used by (Jianying et al., 2021) in assessing priority risks in the fresh grapes supply chain.

Semi-quantitative methods combine the advantages of the two previous approaches by integrating quantitative data and qualitative assessments. This approach provides a more holistic picture of supply chain risk. Semi-quantitative methods successfully provide a comprehensive understanding of risks in supply chains. However, complexity in data integration and analysis and reliance on sophisticated analytical capabilities pose challenges in implementation.

Quantitative

Indicators and risk probabilities may be precisely estimated using quantitative risk assessment. With several benefits over semi-quantitative analysis, it is a rigorous, organized, and systematic technique (Tran et al., 2018). Determining AFSCRA for quantitative methods is divided into six sub-groups: mathematical models, statistical analysis, statistical modelling, spatial modelling, simulation, and others. The sub-group of quantitative methods that are widely used is "statistical analysis" techniques for assessing the risk of agrofood supply chains, including the regression method (Welburn et al., 2016), Ordinary Least Square (OLS) regression model (Nyamah et al., 2017), Principal component analysis (PCA) (Sun et al., 2020; Tian & Li, 2019), Basic descriptive statistics (Heinzova et al., 2022), Factor analysis (Rosales et al., 2020), and Exploratory factor analysis (EFA) (Azmi et al., 2021).

Furthermore, a sub-group of quantitative methods that are widely used is "Simulation". The Agent-based modelling (ABM) method is used by (Ge et al., 2015; Hidayat & Marimin, 2014) in assessing priority risks for the agricultural and palm oil supply chain. The simulation technique using Colored Petri-Net (CPN) is also used by (L. Liu et al., 2018) in assessing and classifying risks for the mackerel supply chain. The system dynamic simulation model is also used by (Azizsafaei et al., 2022) by assessing the operational risk outside the company and macro-level risk aspects in the dairy product supply chain by recommending five scenarios to reduce the impact of risk.

Quantitative supply chain risk assessment methods offer the advantage of providing measurable numerical estimates related to risk events. Using statistical data and mathematical models can provide accurate probability estimates. Quantitative methods have proven effective in predicting risks in supply chains. However, its main drawback is the difficulty in measuring important qualitative aspects such as brand reputation or business partner relationships. This can lead to an incomplete understanding of the risks faced (Abdel-Basset et al., 2019).

Mixed.

When assessing supply chain risk, mixed methods combine or integrate a number of different methodologies. They do this by utilizing the strengths of one methodology to make up for the weaknesses of the other. This approach makes it possible to gain deep insights from multiple perspectives. However, the main challenge is properly integrating the two approaches and managing their complexity (Yin et al., 2018). For instance, (Nakandala et al., 2017) developed a model to measure the level of supply chain risk in fresh food in supermarkets in Australia. The HHM model (qualitative) is combined with fuzzy logic (quantitative) to determine the risk level of a supply chain in terms of macro-level risk, operational risk outside the company, and internal risk, which is then combined using the root mean square (RMS) method to assess the risk level. Get the value of the overall risk level

5. Conclusion

This article thoroughly overviews this research area by reviewing 72 scholarly articles on AFSCRA. This article tries to classify agro-food products, define AFSCRA, classify risk factors, and use methods or approaches in AFSCRA. The journal names chosen for this evaluation span a wide range, including the international journal of production economics, risk analysis, supply chain management, international journal of production research, food control, decision management, and other journals. This means that the study of supply chain risk assessment is quite broad and impacts various aspects. We evaluated the AFSCRA-related literature in this article. According to the findings of the literature review that has been conducted, this study found many studies that focused on supply chain risk for general food (44%), horticultural products (28%), meat products (11%), and dairy products (10%), and only a few are still discussing fishery products (6%) and beverage products (1%). Meanwhile, techniques and approaches in risk assessment in AFSC are more widely used in the semi-quantitative method group (49.3%) and quantitative methods (31.5%) such as AHP, ISM, FAHP, FMEA, HoR, Bayesian Network, Simulation, QMRAs, and others. While qualitative methods (6.9%) and mixed methods (12.3%).

Developing agro-food supply chain risk models among academics and practitioners is anticipated to improve food safety and health assurance. The risk exists because farmers produce food, which is processed before it is delivered to customers for consumption. Researching the risks associated with the agri-food supply chain utilizing novel methodologies, integrating models, methods, and processes, and using information measurement, model quantification and analysis, and decision-making are opportunities for future studies. Risk assessment methods must also be accessible, practical, and reliable given the complexity of agro-food supply chain risk problems. There are also chances to perform extensive, interdisciplinary research involving academics (analysts and modellers) and professionals (decision-makers, policymakers, and other experts).

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