revista GEPROS

Editor Responsável: Prof. Dr. Hermes Moretti Ribeiro da Silva

Recebido:
17/02/2021
Aprovado:
18/04/2022

The Role of Traceability in Food Recall Management: A Systematic Literature Review

João Guilherme Pulita[1], Federal University of São Carlos, São Carlos, São Paulo, Brazil
Helena Canesin[2], Federal University of São Carlos, São Carlos, São Paulo, Brazil
Lucas Lima de Oliveira[3], Federal University of São Carlos, São Carlos, São Paulo, Brazil
Andrea Lago da Silva[4], Federal University of São Carlos, São Carlos, São Paulo, Brazil
Carla Roberta Pereira[5], The Open University Business School, UK

RESUMO

Objetivo – Observou-se uma lacuna acerca da utilização da rastreabilidade no contexto de gestão de riscos em cadeias de suprimentos de alimentos. Os estudos recentes sobre *recalls* de produtos são voltados, em sua maioria, a bens duráveis, enquanto pesquisas direcionadas à gestão de riscos em recalls de alimentos são escassas. Assim, o objetivo deste artigo é compreender como a rastreabilidade influencia na gestão de *recalls* de alimentos.
Referencial Teórico – Inicialmente foram definidos os conceitos fundamentais de rastreabilidade de alimentos, o objetivo e impactos em cadeias de suprimentos. Na sequência, foi descrita sua relação com *recall* de alimentos.
Desenho/metodologia/abordagem – Foi realizada uma revisão sistemática da literatura (RSL). No total, 75 artigos selecionados foram submetidos à análise de conteúdo com o auxílio do software QDA Miner.
Resultados – Foram identificadas dez principais aplicações da rastreabilidade em cadeias de alimentos (com destaque para o papel da transparência) e três grupos de riscos que levam à ocorrência de *recalls* de alimentos (operacionais, biológicos e químicos). Por fim, determinou-se o papel da rastreabilidade antes (fase de preparação - caráter proativo), durante (fase de resposta) e depois (fase de recuperação) da ocorrência de um *recall* de alimentos.
Implicações de pesquisa, práticas e sociais – Os resultados permitem uma melhor compreensão do papel da rastreabilidade na gestão de *recalls* de alimentos.
Originalidade/valor – O artigo sintetiza dez diferentes aplicações da rastreabilidade na cadeia de alimentos, além de explicitar o papel da rastreabilidade nas diferentes etapas da gestão de *recall* de alimentos.
Palavras-chave - Rastreabilidade. *Recall*. Cadeias de Suprimentos. Alimentos.

ABSTRACT

Purpose *- A gap has been observed regarding the use of traceability in the context of risk management in food supply chains. Recent studies on product recalls mostly focus on durable goods, while research aimed at risk management in food recalls is scarce. The aim of this study is to understand how traceability influences food recall management.*
Theoretical framework *- Initially, the fundamental concepts of food traceability, its objective and impacts on supply chains were defined. Then, its relationship with food recalls was described.*
Design/methodology/approach *- A systematic literature review (SLR) was conducted. A total of 75 selected articles were submitted to content analysis using QDA Miner software.*
Findings *- Ten main applications of traceability in food chains (emphasizing the role of transparency) and three groups of risks were identified that lead to the occurrence of food recalls (operational, biological, and chemical). Finally, the role of traceability before (preparation stage - proactive nature), during (response stage), and after (recovery stage) the occurrence of a food recall was determined.*
Research, practical & social implications *- The results provide a better understanding of the role of traceability in food recall management.*
Originality/value *- The article summarizes ten different applications of traceability in the food chain, in addition to explaining the role of traceability in the different stages of food recall management.*
Keywords *- Traceability. Recall. Supply Chain. Food.*

1. Rod. Washington Luiz, s/n - Monjolinho, São Carlos - SP, 13565-905, Brazil, joao.guilherme@estudante.ufscar.br, https://orcid.org/0000-0003-0916-6325; 2. helena.canesin@estudante.ufscar.br, https://orcid.org/0000-0002-9731-8829; 3. lucas.oliveira@estudante.ufscar.br, https://orcid.org/0000-0003-0702-8834; 4. deialago@ufscar.br, https://orcid.org/0000-0003-3849-9698; 5. carla.pereira@open.ac.uk, https://orcid.org/0000-0001-5213-3671.
PULITA, J.G.; CANESIN, H.; OLIVEIRA, L.L.; SILVA, A.L.; PEREIRA, C.R. The Role of Traceability in Food Recall Management: A Systematic Literature Review **GEPROS. Gestão da Produção, Operações e Sistemas**, v.17, nº 2, p. 86 - 110, 2022.
DOI: http://dx.doi.org/10.15675/gepros.v17i2.2881

1. INTRODUCTION

Currently, food supply chains are increasingly complex and fragmented due to the rising globalization of the market, which brought the challenge of ensuring food safety (BEHNKE; JANSSEN, 2020; CASINO *et al*., 2020). Considering this, there has been an increase in vulnerabilities, as the need to transport food over longer distances, for example, exposes it to factors that can cause its contamination (RODRIGUES; TEIXEIRA; SHOCKLEY, 2019). Thus, the culmination of all the risks propagated along the supply chain can cause failures in food quality standards, leading to the need to recall these products (CHAUDHURI *et al*., 2016) and the disruption of the chain in question.

Recall is defined as the removal of a batch or the entire production of a given product from the market, to protect the consumer from potential health risks from the consumption of such food (KUMAR, 2014; JOHNSON-HALL, 2017; BERNON *et al*. 2018). Considering the international landscape, an increasing trend in the number of food recalls is observed. According to Food Standards Australia New Zealand (FSANZ, 2021), there were 87 cases in 2019, while in 2020 this number increased to 109. In the United States, the total number of food recalls rose by 64% between 2019 and 2020, according to data from the Food and Drug Administration (FDA, 2021). In Brazil, meanwhile, according to reports from the National Consumer Secretariat (SENACON) and the Consumer Protection and Defense Program (PROCON), there were 39 recall campaigns in the food sector between 2004 and 2020, and 26 of these only between 2014 and 2020.

Besides the danger to the health of end consumers, it is also noted that the effects of a recall can be substantially negative for firms and their supply chain partners, such as a drop in sales volume and profits (KUMAR; HEUSTIS; GRAHAM, 2015; BERNON *et al*., 2018). Thus, to avoid the aforementioned consequences, the way forward is to prioritize risk mitigation actions in each link of the supply chain (RATHORE; THAKKAR; JHA, 2017). In this context, the implementation of traceability systems helps ensure food safety and quality, as it assists companies in identifying the cause, extent and resolution of problems related to these factors (DABBENE; GAY; TORTIA, 2014; MEDEDJEL; BELALEM; NEKI, 2017; CASINO *et al*., 2020). By limiting the impact of potential problems related to food safety, traceability becomes a relevant tool for risk management in the food sector (RONG; GRUNOW, 2010).

However, it is noted that there is a gap when it comes to the use of traceability in the context of risk management in food supply chains (RINGSBERG, 2014). In addition, there is currently limited understanding of the multiple risks that affect these chains (CHAUDHURI *et al*., 2016). Recent studies on product recalls mostly focus on durable goods, such as cars and toys, while research directed at risk management in food recalls is scarce (JOHNSON-HALL, 2017). In view of all the aforementioned reasons, a systematic literature review is suggested, guided by the following research question: "How does traceability influence the management of food recalls?"

The article is organized as follows: Section 2 presents a review on the main concepts of traceability and food recall; Section 3 presents the methodology, while Section 4 discusses the results of the systematic review. Finally, Section 5 highlights the conclusions, limitations, as well as the theoretical and managerial implications of this research.

2. THEORETICAL FOUNDATION

In general, food traceability can be defined as the ability of organizations to track forward (tracking) or backward (tracing) information related to the movement of products along the supply chain, by capturing, storing, and transmitting this information (BOSONA; GEBRESENBET, 2013; CHARLEBOIS; HARATIFAR, 2015; HALEEM; KHAN; KHAN, 2019). Thus, a food traceability system is able to increase consumer trust and efficiently reduce possible information asymmetries in supply chains (CHEN, 2015).

Aung and Chang (2014) state that companies have three goals in using traceability systems: improve chain management; facilitate traceability for food safety and quality; and promote differentiation and marketing of products with subtle quality attributes. Besides the issues related to food quality and safety, traceability also helps minimize the production and distribution of food that is inadequate for consumption; it identifies the presence of genetically modified organisms in food products; it helps identify the responsible parties, in cases of food safety failures; and it limits the extent of damage caused by the consumption of such products, by means of performing recalls (BOSONA; GEBRESENBET, 2013).

Thus, conducting a recall is somewhat complex, requiring communication at different levels and various documentation procedures (KUMAR; HEUSTIS; GRAHAM, 2015; KODAN; PARMAR; PATHANIA, 2020). Usually, a food recall is performed for failures related to inadequate production practices, such as poor labeling or food packaging; to a lack of control over contamination, especially in fresh products and semi-processed foods with allergens (such as eggs, milk, or gluten); to a lack of control over production conditions (which may include the addition of chemicals, the presence of microbiological agents, and processes); and to inadequate control of external factors, such as temperature and humidity (RINGSBERG, 2014).

According to Regattieri, Gamberi, and Manzini (2007), only an efficient tracking system is able to perform a recall safely, enabling a better search for the causes of such an event. However, as Kumar, Heustis and Graham (2015) point out, one of the factors that contribute to the lack of traceability is that many companies cannot reach their entire supply chain as the technological systems are not always integrated among their suppliers.

3. METHODOLOGICAL PROCEDURES

This article develops a systematic literature review (SLR), according to the stages proposed by Tranfield, Denyer and Smart (2003). When performing a systematic review, the work is carried out in an orderly and methodical manner, avoiding random or haphazard approaches (JESSON; MATHESON; LACEY, 2011), and, therefore, ensures rigor, replicability and, consequently, relevant results to the research (PEREIRA; CHRISTOPHER; SILVA, 2014). Table 1 details the protocol followed in this research.

Table 1 – Protocol of the systematic literature review

Stage	Details
Scope study	- Search for the themes Risk Management, Recall and Traceability in the main journals in the area of Operations and Supply Chain to identify constructs and keywords in order to direct the formulation of research questions.
Conducting the review	- Search in the databases: EBSCO, Compendex, Scielo, Scopus and Web of Science.
	- Searches until September 2020 with no start restriction.
	- Use of the Parsifal tool to exclude duplicates.
	- 1st filter: title and abstract reading and key words screening.
	- 2nd filter: introduction, conclusion and analysis of inclusion and exclusion criteria.
	- 3rd filter: reading and evaluation of full articles.
Data analysis	- Careful reading of the papers.
	- Use of QDA Miner software to code and analyze the content based on what was intended to be answered from the research questions.
	- Content analysis of the selected articles to answer the review questions using the QDA Miner tools.

Source: Adapted from Tranfield, Denyer and Smart (2003).

This research began with a scope study, based on the search for papers in the main journals in the areas of risk management, recall, and traceability. The purpose of this stage was to elucidate the problematic regarding the use of traceability as a food recall management tool, verifying the gaps in previous studies to define the questions to be explored in this research. Together, the keywords pertinent to each question were analyzed, to facilitate the construction of strings used to perform the SLR. These data are presented in Table 2.

Table 2 – SLR questions, keywords and search strings

Review Questions	Keywords	Strings
1) What are the main applications of traceability in the food supply chain?	Traceability Track Food Supply chain Supply net Value chain Net chain Net value	(“trac*”) AND ((“food*”) NEAR/5 (“supply chain*” OR “supply net*” OR “value chain*” OR “net* chain” OR “net* value”))
2) What are the main types of risks in recall in the food supply chain?	Risk Hazard Threat Food Recall Supply chain Supply net Value chain Net chain Net value	((“risk*” OR “hazard*” OR “threat*”) AND “recall*”) AND (“food*” AND (“supply chain*” OR “supply net*” OR “value chain*” OR “net* chain” OR “net* value”))
3) What is the role of traceability in recall management in food supply chains?	Risk Hazard Threat Disaster Disruption Food Recall Traceability Track Supply chain Supply net Value chain Net chain Net value	((“risk*” OR “hazard*” OR “threat*” OR “disruption*” OR “disaster*”) AND “trac*” AND “recall*”) AND (“food*” NEAR/5 (“supply chain*” OR “supply net*” OR “value chain*” OR “net* chain” OR “net* value”))

Source: Authors (2021).

The searches were conducted in the Scopus, Web of Science, EBSCO, Scielo and Compendex databases as the systematic review aims to locate, select and analyze the largest possible amount of relevant research to the question investigated (DENYER; TRANFIELD, 2009). Furthermore, criteria for inclusion and exclusion of articles were adopted, which should be explained in detail to allow the understanding of these decisions, to select relevant articles to the object of study (DENYER; TRANFIELD, 2009). These criteria are shown in Table 3.

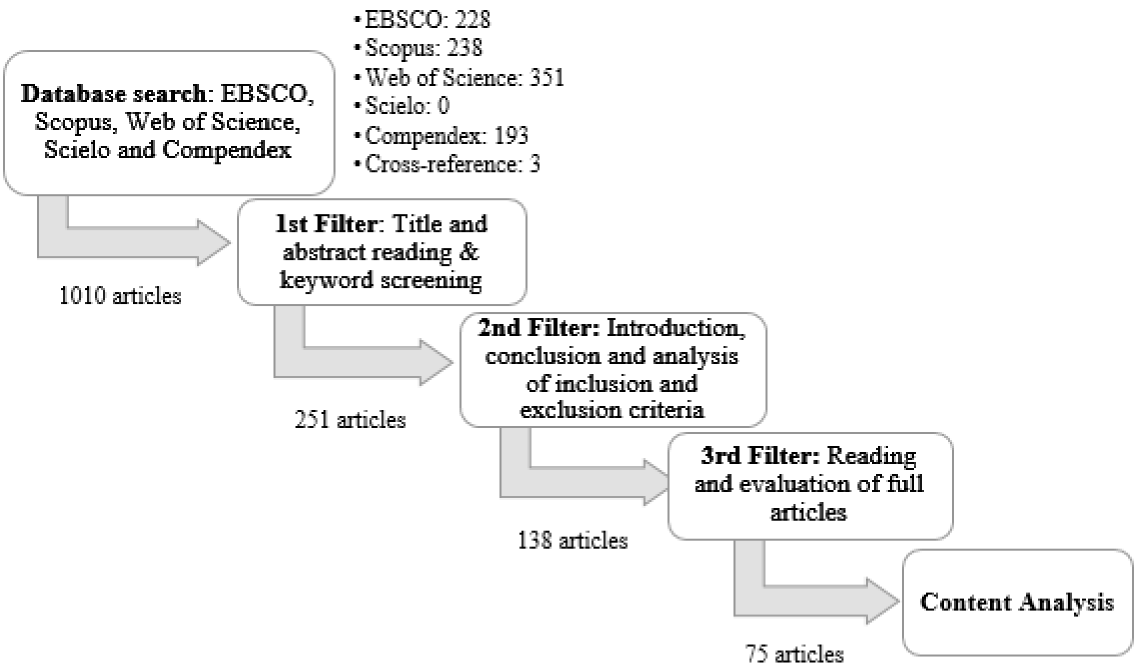
Table 3 – Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Access	Must be written in English or Portuguese.	No access to the work. Not written in English or Portuguese.
Document Type	Peer-reviewed scientific journal.	Business journals, current magazines, books, conferences, reports and websites.
Focus	Traceability and Recall in an operations management and supply chain context.	Concepts related to medicine, nursing, psychology, biochemistry, molecular biology, pharmacology, energy, and veterinary science.
Recall	To address recall in the sense of removal of a product in a supply chain.	Do not refer to the concept of removal; address recall in the sense of remember; use to take up a quote and/or concept.
Traceability	To address applications of traceability in food supply chains.	Do not refer directly to traceability applications in food supply chains.
Analysis Unit	The entire food supply chain.	Communities or not related to food supply chains.

Source: Authors (2021).

Articles were selected after defining the above criteria. In total, the databases returned 1010 articles, of which 472 were duplicates. The elimination of the duplicate documents was carried out using the Parsifal tool. Three articles were included by cross-reference, which went through the same filters and analysis criteria as the other articles. Finally, after full reading and evaluation, 75 articles were selected for content analysis. The results obtained in each stage of the selection can be seen in Figure 1.

Figure 1 – Filtering stages of the selected articles



Source: Authors (2021).

In the content analysis stage, the QDA Miner software was used for coding the selected articles. Based on the requirements proposed by Krippendorff (2013), a codebook was prepared to categorize and code the available data in a mutually exclusive and exhaustive manner. Prior reading of the articles was performed, and with the help of experts, the initial codifications were identified. Later, from reviews and detailed reading, the final codings were established. Moreover, during the reading, new codifications were added, removed, or unified, as needed. After entering the articles into the software, all articles were assigned the variables "author's name", "year of publication", "method used", and "journal".

For qualitative analyses, the co-occurrence analysis was used, which occurs when two or more codes appear in the same article (QDA MINER, 2021). This analysis considers information about the proximity or co-occurrence of codings, which allows locating relationships between codes or between cases (QDA MINER, 2021). In this project, Jaccard's coefficient was used for all co-occurrence analyses, which assigns equal weight to cases where co-occurrence is identified (a) and to cases where one item is found but not the other (b and c). Thus, it is calculated from a quadruple table as a/(a + b + c) (QDA MINER, 2021).

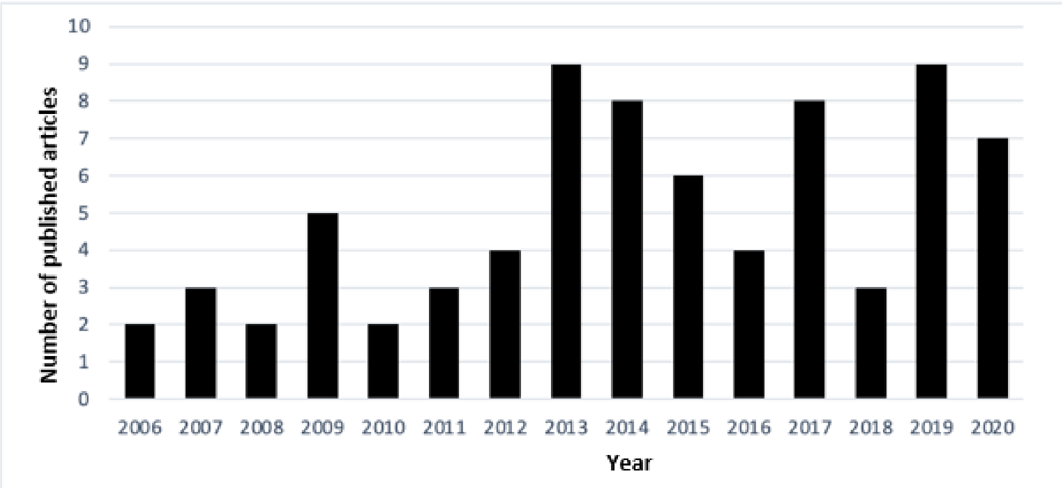
The co-occurrence analysis made it possible to understand the groupings of the types of food recall risks identified and the relationships between traceability applications in the food chain.

4. RESULTS AND DISCUSSION

4.1 Descriptive Analysis

Figure 2 shows the distribution of published articles by year. Thus, a significant increase in publications is observed from 2013 onwards, with an annual average of six articles from the year in question until 2020.

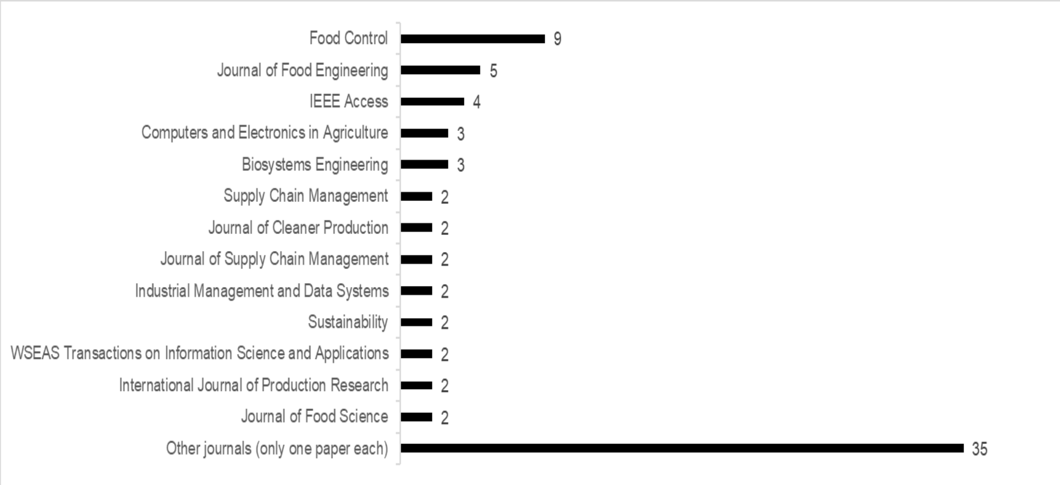
Figure 2 - Article publication frequency by year



Source: Authors (2021).

The articles were published in 48 different peer-reviewed journals. Figure 3 shows the 13 journals that presented, at least, more than one article in this review. Noteworthy among the most cited are the high impact factor journals Food Control and Journal of Food Engineering, which focus on food safety and engineering research, respectively.

Figure 3 - Frequency of article publication by journal



Source: Authors (2021).

Regarding the methodologies used in the analyzed articles (Table 4), the Literature Review method stands out. It is also noteworthy that, within the "Literature Review" classification, there are two articles that conducted systematic literature reviews. The "mixed method" classification was used for articles that combined two or more methods together.

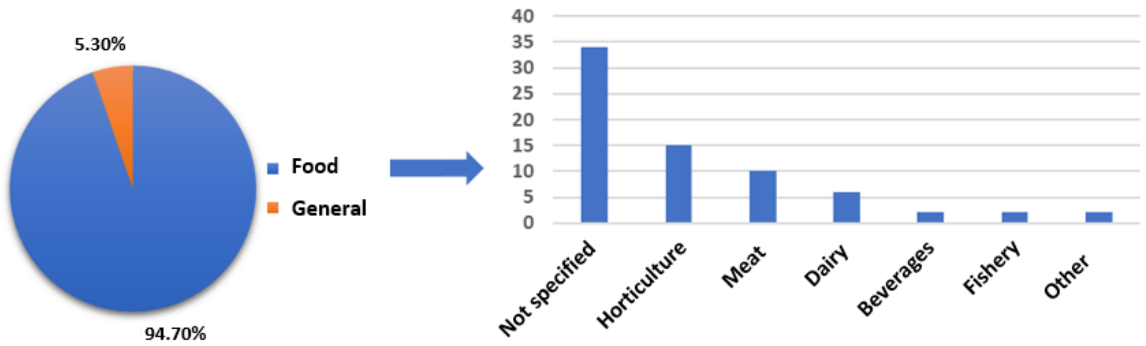
Table 4 - Frequency of methodologies applied in the selected articles

Method	Number of articles
Literature review	24
Mixed Method	16
Case study	14
Modeling	14
Survey	3
Simulation	2
Experiment	1
Delphi Method	1
TOTAL	**75**

Source: Authors (2021).

Finally, regarding the industries addressed in the selected works (Figure 4), the food industry stands out, addressed in 71 articles. Of these, the majority (34) did not focus on a specific segment, while the others focused mainly on horticulture (15), meat (10), and dairy products (6).

Figure 4 - Types of industries addressed in the selected articles



Source: Authors (2021).

4.2 Main traceability applications in food supply chains

Throughout the SLR, ten main applications of traceability were identified in the food chain, which are summarized in Table 5, together with the related authors.

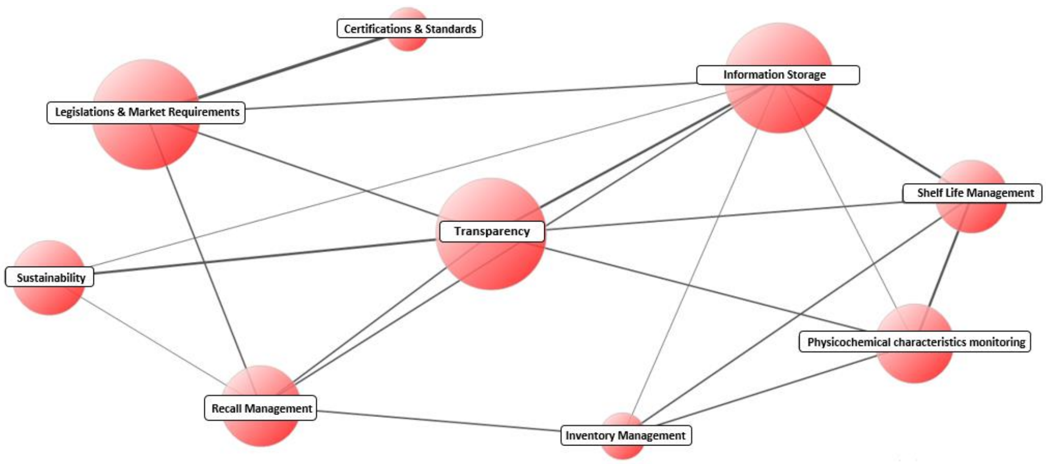
Table 5 - Main traceability applications in food chains

Application	Description	Authors
Information Storage	Store historical data on product flow securely for tracking purposes from producer to point of sale.	Bertolini, Bevilacqua and Massini (2006); Storoy, Thakur and Olsen (2013); Aung and Chang (2014); Ringsberg (2014); Salah et al. (2019).
Certifications and standards	Obtain ISO 22005 certification and standards such as GS1, GlobalGAP, British Retail Consortium (BRC), International Standard for Auditing Food Suppliers (IFS) and Safe Quality Food (SQF).	Storoy, Thakur and Olsen (2013); Aung and Chang (2014); Dabbene, Gay and Tortia (2014).
Shelf life management	Identify and classify foods with regard to their shelf life, especially perishable products.	Wang, Li and Li (2009); Zou et al. (2014); Galvez, Mejuto and Simal-Gandara (2018); Tsang et al. (2019).
Inventory management	Obtain real-time information on the status and quantities of products in stock.	Kumar et al. (2009); Wang, Li and Li (2009).
Recall management	Minimize the occurrence, scope, cost and time of food recalls	Kelepouris, Pramatari and Doukidis (2007); Wang, Li and Li (2009); Kumar, Heustis and Graham (2015).
Legislations	Comply with regulations imposed by countries and economic blocks, whether mandatory or not.	Gessner, Volonin and Fish (2007); Thakur, Martens and Hurburgh (2011); Wognum et al. (2011); Bosona and Gebresenbet (2013); Aung and Chang (2014); Kumar, Heustis and Graham (2015).
Physicochemical characteristics monitoring	Control food temperature, humidity and nutritional quality in real time, in order to reduce losses caused by quality deterioration due to the variation of such parameters.	Exposito, Gay-Fernandez and Cuinas (2013); Aung and Chang (2014); Parreno-Mercante et al. (2014); Thakur and Foras (2015); Alfian et al. (2017); Dong et al. (2020).
Market requirements	Meet the requirements of markets that demand traceability, such as meat exports to the EU.	Klein et al. (2014).
Sustainability	Monitor the carbon footprint of the production process, build trust among stakeholders by managing traceability records and serve as proof of food authenticity.	Wognum et al. (2011); Farooq et al. (2016); Feng et al. (2020).
Transparency	Promote visibility along the chain, allowing the collection and dissemination of information to all agents.	Bertolini, Bevilacqua and Massini (2006); Galvez, Mejuto and Simal-Gandara (2018); Chan, Abdullah and Khan (2019); Dong et al. (2020).

Source: Authors (2021).

From the codification of the articles by QDA Miner, the relations between these traceability applications could be analyzed. This task was performed as from the co-occurrence analysis between the codings, as illustrated in Figure 5. It is noteworthy that the size of the bubbles indicates the frequency with which this application was coded (i.e., the frequency with which it appeared in the discussion of the articles), and the thickness of the traces connecting them indicates the degree of relationship between the applications (i.e., how much they were discussed together).

Figure 5 - Relationship between food traceability applications



Source: Authors (2021).

Based on Figure 5, it is possible to visualize that the main food traceability applications found address the compliance with legislations and market requirements, the promotion of transparency along the chain and the storage of food information, such as origin, flow and destination. In addition, it is also possible to visualize the central role of transparency and its relationship with basically all other applications. This is because without transparency, traceability cannot be implemented, as transparency must come first so that information about traceability, such as origin and processes that occurred from the supplier, can be collected for the purpose of meeting safety, sustainability and social responsibility requirements (CHAN; ABDULLAH; KHAN, 2019). Thus, companies that implement traceability systems increase the visibility of their chains, meet the demands of their customers (who demand transparency in the processes applied to the products they consume), share essential information with other members of the chain, such as certifiers and NGOs, and therefore comply with current legislations (EXPOSITO; GAY-FERNANDEZ; CUINAS, 2013; DONG *et al.*, 2020; KODAN; PARMAR; PATHANIA, 2020).

It also highlights the strong connection between shelf-life management with the monitoring of food characteristics and the storage of this information, which can be used to identify and classify items in relation to their shelf life (ZOU *et al.*, 2014). One also notes the connection between recall management with legislation and market requirements, such as the Bioterrorism Preparedness and Response Act, which provides safety and security guidelines for the US food and beverage industry focusing on preventing bioterrorist attacks (GESSNER; VOLONIN; FISH, 2007). Moreover, the management of recalls also relates to transparency and information storage, especially from information technologies such as Blockchain and RFID, as stated by Mondal *et al.* (2019) and Regattieri, Gamberi, and Manzini (2007). Section 4.4 will address in more depth the role of traceability in food recall management. Finally, the strong and exclusive relationship between obtaining standards and certifications with compliance with legislations and market requirements can also be observed, since, from the reviewed material, it could be observed that a common point between both applications is to use traceability to comply with demands external to the company.

4.3 Main risks of recalls in food chains

According to the literature, the main causes of food recalls are related to: production failures; inadequate packaging and labeling; contamination by pathogens, chemical additives, toxins, pesticides, allergens, and external particles (such as glass and metal fragments); improper heat treatment; and economically motivated adulteration (DABENNE; GAY; TORTIA, 2014; RINGSBERG, 2014; CHARLEBOIS; HARAFITAR, 2015; ALLATA; VALERO; BENHADJA, 2017; JOHNSON-HALL, 2017). In order to segment such causes in their study, Potter et al. (2012) classify recall-related risks into three groups: biological, chemical and operational. Table 6 presents the risk groups, related to their respective causes, along with the main authors found in this SLR.

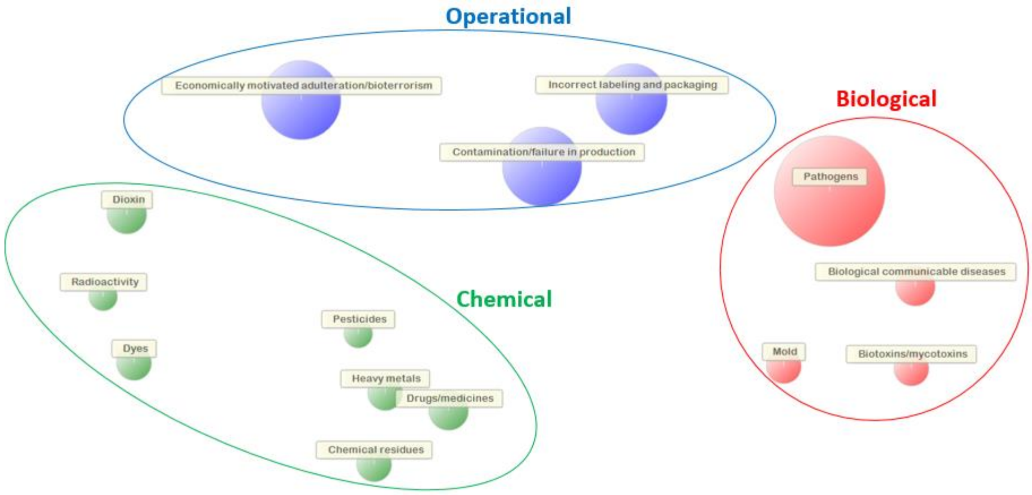
Table 6 - Main risks and causes associated to food recalls

Risk	Causes	Authors
Operational	Related to incorrect labeling and packaging, contamination in production and economically motivated adulteration or terrorism.	Gessner, Volonino and Fish (2007); Potter et al. (2012); Kumar (2014); Johnson-Hall (2017).
Biological	Include contamination by pathogens, mold, biotoxins, mycotoxins, and communicable diseases.	Gessner, Volonino and Fish (2007); Potter et al. (2012); Piramithu, Farahani and Grunow (2013); Allata, Valero and Benhadja (2017).
Chemical	Associated with the presence of dyes, drugs, medicines, pesticides, chemical residues, heavy metals and radioactivity.	Wang, Li and Li (2009); Potter et al. (2012); Charlebois and Haratifar (2015); Allata, Valero and Benhadja (2017).

Source: Authors (2021).

In order to identify the main risks in the analyzed literature, QDA Miner was used to analyze the co-occurrence between risks (Figure 6). Once more, the size of the bubbles indicates the frequency of occurrence of the risks in the analyzed articles, while the proximity between them indicates a possible grouping. Thus, it is intended to validate the classification used in this review.

Figure 6 – Risks associated with food recalls



Source: Authors (2021).

At first, Figure 6 shows three groupings: in blue, operational risks; in red, biological risks; and in green, chemical risks. Thus, as the figure points out, the main risk associated with food recalls is due to contamination caused by pathogens. Moreover, this cause represents most of the risks associated with biological factors, which is in agreement with the literature. Finally, it was observed a low and almost uniform frequency among chemical risks, which shows the low volume of research in this category compared to the others. From all these findings, one can conclude that the results obtained with this SLR converge with the study of Potter *et al.* (2012) as operational risks are the most frequent causes of food recalls, while chemical risks are the least representative and the main biological risk is caused by pathogens.

4.4 Role of traceability in food recall management

In order to answer what is the role of traceability in food recall management, this research sought to relate the three stages of supply chain disruption management addressed by

Scholten, Scott, and Fynes (2019), namely Preparation, Response and Recovery, with the stages of recall (before, during and after) and the different roles of traceability. The aim is to understand the role of traceability in each of the recall management stages. Considering Bischof and Wilfinger (2019), while the preparation stage has a proactive character (i.e., before a recall occurs), the other stages have a reactive character (after the recall occurs). Thus, the articles that presented traceability functions in food recall management were coded according to the three stages of disruption management presented. Then, the codings were analyzed and synthesized to group the traceability roles in each of these stages. Table 7 summarizes the traceability roles during the food recall management stages, which will be detailed below.

Table 7 - Traceability's role in food recall management

Disruption Management Stages	Recall Stages	Role of traceability	Authors
Preparation	**Before**	Identification of nonconformities along the chain.	Charlebois and Haratifar (2015); Tang et al. (2015); Purwandoko et al. (2019).
		Record information related to origin, raw materials, processing and resources used.	Hu et al. (2009); Thakur, Martens and Hurburgh (2011); Bosona and Gebresenbet (2013).
		Reduction of food fraud and counterfeiting.	Charlebois and Haratifar (2015).
		Reduction in the production and distribution of unsafe products for consumption.	Wang, Li and Li (2009).
		Food quality control and assurance.	Wang, Li and Li (2009); Wang, Yue and Zhou (2017); Tsang et al. (2019).
Response	**During**	Identification of affected parties.	Kumar (2014); Mededjel, Belalem and Neki (2017).
		Minimization of recall scope.	Wang, Li and Li (2009); Lin et al. (2020).
		Speed in carrying out the recall.	Costa et al. (2013); Ringsberg and Mirzabeiki (2014).
		Identification of the source of contamination.	Mededjel, Belalem and Neki (2017).
		Cost reduction.	Kelepouris, Pramatari and Doukidis (2007); Lin et al. (2020).
		Limitation of consumer exposure to unsafe food.	Adam et al. (2016).
Recovery	**After**	Process improvement.	Skilton and Robinson (2009).
		Identification of recall cause.	Bhatt, Hickey and McEntire (2013).
		Information provision for accountability.	Piramuthu, Farahani and Grunow (2013).
		Data provision for recall prevention.	Adam et al. (2016).

Source: Authors (2021).

4.4.1 Preparation (before recall)

According to Tang *et al.* (2015), a food traceability system is a proactive strategy based on information for food safety management. This system facilitates the identification of food risks and orderly recalls in the event of an incident to prevent food safety hazards (TANG *et al.*, 2015) and helps reduce food fraud and counterfeiting (CHARLEBOIS; HARATIFAR, 2015). Thus, traceability systems can be risk mitigation tools for all actors in the chain, as they are able to identify non-compliances throughout the different stages of food processing (PURWANDOKO *et al.*, 2019). Traceability systems equipped with technological innovations can provide real-time information on food quality and safety statuses, which enables quick recalls when the standards of such statuses are violated and increases the transparency of the chain (WANG; LI; LI, 2009; WANG; YUE; ZHOU, 2017).

Moreover, real-time traceability data, such as transportation history and temperature logging, allows to quickly identify the source of a problem in a supply chain and correct it quickly and efficiently (WANG; LI; LI, 2009). Thakur, Martens, and Hurburgh (2011) highlight the role of the ability to link outbound batch information (shipments) to inbound batches as important in emergency food safety situations. Other relevant information that traceability systems should record to help manage such situations includes: a) food/feed origin and types, ingredients, authenticity, species and age (for beef); b) processes in all stages of the supply chain (primary production, further processing, testing, storage, distribution, retail, consumption); and c) resources used (people, machines, transportation equipment) (BOSONA; GEBRESENBET, 2013).

4.4.2 Response (during recall)

Costa *et al.* (2013) state that the real value of traceability is represented by the shortest time needed to intervene in the case of food safety incidents, where there is a need to recall the entire stock from the market and individualize the source of the problem. Thus, Adam *et al*. (2016) report that a robust traceability system throughout the chain can provide the basis for an accurate and timely recall following a foodborne illness outbreak, as well as limiting consumer exposure to potentially dangerous food and company liability. In this regard, Ringsberg and Mirzabeiki (2014) also state that the speed in conducting food recalls is verified by implementing RFID technology, which provides a reduction in the time to identify affected products.

According to Kumar, Heustis, and Graham (2015), a good traceability system should be able to determine at what stages and at what time an error occurred, should something go wrong. Considering food recalls, traceability tools allow companies to identify where contaminated products come from, in addition to being able to track the delivery truck that transports such products and even identify the stores and shelves where they are displayed (MEDEDJEL; BELALEM; NEKI, 2017).

According to Gessner, Volonino, and Fish (2007), the less complete and accurate the traceability records are, the greater the safety margins of a recall (i.e., the quantity to be recalled), leading to the recall of many uncontaminated products due to uncertainty. Thus, Wang, Li, and Li (2009) point out that an effective traceability system helps to reduce the potential scope of a food recall and the volume of products that must be recalled, as it can identify problem batches, isolate them, and locate the products related to potential health risks, enabling the provision of accurate information to the public (TANG *et al*., 2015). Lin *et al.* (2020) highlight the role of Blockchain that allows purchasing managers to track all information online in real time, which enables the easy location of individual contaminated products without the need to recall all associated products.

Finally, Kelepouris, Pramatari, and Doukidis (2007) state that once a food-related outbreak is identified, a traceability information system can reduce recall costs. This happens due to the precise direction to the product batches that must be withdrawn from the market, occurring in lower costs with lost sales, product discard and damage to the company's market profile.

4.4.3 Recovery (after recall)

According to Regattieri, Gamberi and Manzini (2007), an effective recall and search for what caused the problems is only possible with an efficient tracking system. This involves, according to Bhatt, Hickey and McEntire (2013), an investigation based on upstream tracing (documenting the distribution paths of products from various locations) to determine whether there is a point of convergence in the supply chain, such as common date and harvest or manufacturing locations. The same authors argue that determining this convergence point is a critical factor in conducting an origin investigation to determine how the contamination occurred and prevent future problems.

For producers, on the other hand, traceability is seen as a part of a cost-effective overall quality management system that can help continuous improvement and minimizing the impact of safety-related risks (AUNG; CHANG, 2014). According to Kumar (2014), continuous improvement is an important requirement for the progress of any company. The author argues that, once a recall is completed, it is important for companies to evaluate their processes to improve them. That is, as defects or adverse events occur in a process, traceability is used to discover the causes of such variations, which can lead to the development of improved controls or processes (SKILTON; ROBINSON, 2009).

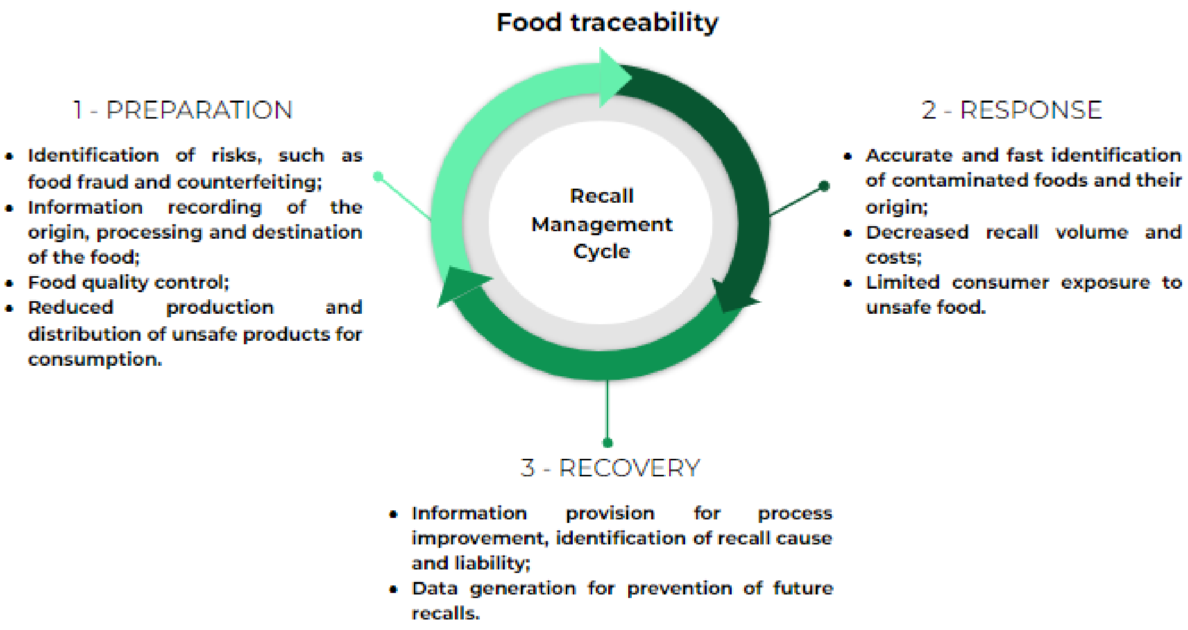
Moreover, according to Piramuthu, Farahani, and Grunow (2013), the choice of the level of traceability and the technology involved does not only imply costs, but also influences the responsibility of the different supply chain members. Thus, the authors define liability as the cost incurred when contamination is detected. Thus, ultimately, identifying the source of contamination facilitates the isolation and correction of the cause of the contamination, payment for damages caused by the "guilty party, and exoneration or compensation of the "innocent" parties. That is, once identified, the agent responsible for the contamination pays the cost of the product recall (PIRAMITHU; FARAHANI; GRUNOW, 2013).

Finally, Adam *et al.* (2016) argue that the use of Big Data Analytics in a traceability system that encompasses the entire chain can relate producer data to consumer data, generating a large repository. According to the authors, such data can be used by analytics algorithms to create an early detection system for animal diseases, food safety issues and bioterrorism. In addition, they can also be used for prediction, clustering, association, correlation, classification and optimization of foodborne outbreaks (ADAM *et al.*, 2016). Thus, the authors conclude that this can result in better and faster decision making, which helps faster and more effective responses in the face of foodborne outbreaks. Thus, Li et al. (2017) also relate the use of data analytics to extract important information that helps the supply chain management of prepackaged food.

6. CONCLUSION

It is a fact that risks are inherent to food supply chains as they are increasingly globalized and subject to disruptions. However, it is desirable that companies try to mitigate such risks through tools such as traceability, to avoid the occurrence of crises and outbreaks related to food safety and quality that impact the lives of final consumers. Thus, this research is unprecedented in characterizing the role of traceability in managing food recalls; that is, not only in mitigating risks which lead to recalls, but also during and after such a process. Figure 7 summarizes the main contribution of this review, which is the role of traceability in each stage of the recall management cycle, from the preparation stage to the recall response and subsequent recovery.

Figure 7 – Food Traceability in the Recall Management Cycle



Source: Authors (2021).

Thus, the cycle begins in Stage 1 (Preparation), in which traceability acts as a risk identification and quality control tool, to avoid the occurrence of a recall. However, as such an event is not always avoidable, in this stage there is also the preparation for an eventual recall, with the registration of information related to the origin, manufacturing, and distribution of the food. Thus, once the need to recall is verified, the cycle moves to Stage 2

(Response), in which the role of traceability is to quickly and accurately identify the affected foods and the origin of their contamination to minimize costs and exposure of final consumers to risks. Finally, after the recall is carried out, the cycle moves on to Stage 3 (Recovery), in which traceability provides information that makes it possible to identify the cause of the recall and those responsible for its occurrence, in addition to data aimed at improving traceability processes and systems to prevent future events. Based on this information, new strategies to mitigate recalls can be designed, and the cycle begins again in Stage 1, with the preparation for a new event.

At the managerial level, the results of this research allow food chain professionals to have an understanding of the importance of food traceability, as well as the main risks that generate recalls, in order to design efficient mitigation strategies. Moreover, it presents a framework of possible uses of traceability during the management stages of a food recall, expanding the literature on the subject. Finally, it is noteworthy that, despite the specific scope of this study, recalls are not restricted only to the food industry; therefore, the contributions identified here can help other industries, such as pharmaceuticals and consumer goods in general.

Some points should be highlighted in the literature reviewed. First, the increasing use of information technologies (ITs), particularly Blockchain, in food traceability systems was identified (FENG *et al*., 2020). However, although this review did not focus on the use of ITs, no reviewed articles used the technology exclusively for recalls management. Thus, future research can be directed toward investigating the role of ITs in supporting food recalls from the use of traceability systems. Another point that should be investigated further would be to identify the motivations and barriers to the adoption of IT-based traceability systems, having as one of its applications the recall events. Moreover, a possible question to be investigated would be the impacts of the use of such systems from the point of view of the final consumer (preferences and willingness to pay). Finally, among the 75 articles reviewed, only two were based on Brazilian food chains, which shows the need for research in the area of food traceability in the country. There were also few papers in the literature on food recalls caused by chemical hazards, when compared to other hazards (biological and operational). Thus, additional research can focus on such risks to fill this gap.

This research has some limitations. First, only peer-reviewed articles written in English or Portuguese were reviewed. Thus, it is possible that relevant research on the topic that did not meet these requirements was excluded from this selection and analysis. Second, this research presented a literature review of a generic food supply chain and some particularities of specific food chains could be better explored (cold chain, for example). Thus, since not all applications or risks are present in the different segments (such as meat, dairy, and horticulture), it is possible that not all traceability roles in recall management are useful for all of these segments. To this end, future research may focus only on some segments in order to deepen the understanding of the problem. Third, as this is a literature review, empirical data was not gathered. Thus, we encourage future studies in comparing the conclusions obtained from this paper with case studies of real companies that have experienced food recalls and used traceability systems along their supply chains.

Acknowledgments

The authors would like to thank the São Paulo State Research Support Foundation (FAPESP) for supporting the project through processes 2019/10425-5, 2020/06309-7 and 2020/04329-0, and CNPq for PQ grant 304241/2019-9 in the related topic.

References

ADAM, B. D.; HOLCOMB, R.; BUSER, M.; MAYFIELD, B.; THOMAS, J.; O'BRYAN, C. A.; CRANDALL, P.; KNIPE, D.; KNIPE, R.; RICKE, S. C. Enhancing Food Safety, Product Quality, and Value-Added in Food Supply Chains Using Whole-Chain Traceability. **International Food and Agribusiness Management Review**, v. 19, p. 191–213, 2016.

ALFIAN, G.; RHEE, J.; AHN, H.; LEE, J.; FAROOQ, U.; IJAZ, M. F.; SYAEKHONI, M. A. Integration of RFID, wireless sensor networks, and data mining in an e-pedigree food traceability system. **Journal of Food Engineering**, v. 212, p. 65–75, 2017.

ALLATA, S.; VALERO, A.; BENHADJA, L. Implementation of traceability and food safety systems (HACCP) under the ISO 22000:2005 standard in North Africa: The case study of an ice cream company in Algeria. **Food Control**, v. 79, p. 239–253, 2017.

AUNG, M. M.; CHANG, Y. S. Traceability in a food supply chain: Safety and quality perspectives. **Food control,** v. 39, p. 172-184, 2014.

BEHNKE, K.; JANSSEN, M. Boundary conditions for traceability in food supply chains using blockchain technology. **International Journal of Information Management**, v. 52, p. 101969, 2020.

BERNON, M; BASTL, M.; ZHANG, W.; JOHNSON, M. Product recalls: The effects of industry, recall strategy and hazard, on shareholder wealth. **International Journal of Business Science and Applied Management**, v. 13, n. 1, p. 1–14, 2018.

BERTOLINI, M.; BEVILACQUA, M.; MASSINI, R. FMECA approach to product traceability in the food industry. **Food Control**, v. 17, n. 2, p. 137–145, 2006.

BHATT, T.; HICKEY, C.; MCENTIRE, J. C. Pilot projects for improving product tracing along the food supply system. **Journal of food science**, v. 78 Suppl 2, n. September 2011, p. B34–B39, 2013.

BISCHOF, C.; WILFINGER, D. Big data-enhanced risk management. **Transactions of Famena**, v. 43, n. 2, p. 73–84, 2019.

BOSONA, T.; GEBRESENBET, G. Food traceability as an integral part of logistics management in food and agricultural supply chain. **Food control**, v. 33, n. 1, p. 32-48, 2013.

CASINO, F.; KANAKARIS, V.; DASAKLIS, T. K.; MOSCHURIS, S; STACHTIARIS, S; PAGONI, M.; RACHANIOTIS, N. Blockchain-based food supply chain traceability: a case study in the dairy sector. **International Journal of Production Research**, p. 1-13, 2020.

CHAN, K. Y.; ABDULLAH, J.; KHAN, A. S. A framework for traceable and transparent supply chain management for agri-food sector in malaysia using blockchain technology. **International Journal of Advanced Computer Science and Applications**, v. 10, n. 11, p. 149–156, 2019.

CHARLEBOIS, S.; HARATIFAR, S. The perceived value of dairy product traceability in modern society: An exploratory study. **Journal of Dairy Science**, v. 98, n. 5, p. 3514–3525, 2015.

CHAUDHURI, A.; SRIVASTAVA, S. K.; SRIVASTAVA R. K.; PARVEEN, Z. Risk propagation and its impact on performance in food processing supply chain. **Journal of Modelling in Management**, v. 11, n. 2, p. 660–693, 2016.

CHEN, R. Y. Autonomous tracing system for backward design in food supply chain. **Food Control**, v. 51, p. 70–84, 2015.

COSTA, C.; ANTONUCCI, F.; PALLOTTINO, F.; AGUZZI, J; SARRIÁ, D.; MENESATTI, P. A Review on Agri-food Supply Chain Traceability by Means of RFID Technology. **Food and Bioprocess Technology**, v. 6, n. 2, p. 353–366, 2013.

DABBENE, F.; GAY, P.; TORTIA, C. Traceability issues in food supply chain management: A review. **Biosystems Engineering**, v. 120, p. 65–80, 2014.

DENYER, D.; TRANFIELD, D. Producing a systematic review. **The Sage handbook of organizational research methods**. Sage Publications Ltd, 2009.

DONG, Y.; FU, Z.; STANKOVSKI, S.; WANG, S.; LI, X. Nutritional Quality and Safety Traceability System for China's Leafy Vegetable Supply Chain Based on Fault Tree Analysis and QR Code. **IEEE Access**, v. 8, n. Figure 1, p. 161261–161275, 2020.

FAROOQ, U.; TAO, W.; ALFIAN, G.; KANG, Y.; RHEE, J. EPedigree traceability system for the agricultural food supply chain to ensure consumer health. **Sustainability (Switzerland)**, v. 8, n. 9, p. 1–16, 2016.

FENG, H.; WANG, X.; DUAN, Y.; ZHANG, J.; ZHANG, X. Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. **Journal of Cleaner Production**, p. 121031, 2020.

Food and Drug Administration (FDA). **Recalls, Market Withdrawals, & Safety Alerts**. Available at: <https://www.fda.gov/>. Access on: 10 Sep. 2021.

Food Standards Australia New Zealan (FSANZ). **Food recalls**. Available at: <http://www.foodstandards.gov.au/industry/foodrecalls/pages/default.aspx>. Access on: 10 Sep. 2021.

GALVEZ, J. F.; MEJUTO, J. C.; SIMAL-GANDARA, J. Future challenges on the use of blockchain for food traceability analysis. **TrAC - Trends in Analytical Chemistry**, v. 107, p. 222–232, 2018.

GESSNER, G. H.; VOLONINO, L.; FISH, L. A. One-up, one-back ERM in the food supply chain. **Information Systems Management**, v. 24, n. 3, p. 213–222, 2007.

HALEEM, A.; KHAN, S.; KHAN, M. I. Traceability implementation in food supply chain: A grey-DEMATEL approach. **Information Processing in Agriculture**, v. 6, n. 3, p. 335-348, 2019.

HU, Z.; JIAN, Z.; XIAOSHUAN, S.; WEISONG, M. Modeling method of traceability system based on information flow in meat food supply chain. **WSEAS Transactions on Information Science and Applications**, v. 6, n. 7, p. 1094–1103, 2009.

JESSON, J.; MATHESON, L.; LACEY. **Doing your literature review: Traditional and systematic techniques**. Sage, 2011.

JOHNSON-HALL, T. D. Ensuring food safety by preventing food recalls: The impact of locus of failure, regulatory agency discovery, breadth, and firm size on corrective action. **Journal of Marketing Channels**, v. 24, n. 3-4, p. 115-135, 2017.

KELEPOURIS, T.; PRAMATARI, K.; DOUKIDIS, G. RFID-enabled traceability in the food supply chain. **Industrial Management and Data Systems**, v. 107, n. 2, p. 183–200, 2007.

KLEIN, A. Z.; DA COSTA, E. G.; VIEIRA, L. M.; TEIXEIRA, R. The use of mobile technology in management and risk control in the supply chain: The case of a Brazilian beef chain. **Journal of Global Information Management**, v. 22, n. 1, p. 14–33, 2014.

KODAN, R.; PARMAR, P.; PATHANIA, S. Internet of Things for Food Sector: Status Quo and Projected Potential. **Food Reviews International**, v. 36, n. 6, p. 584–600, 2020.

KRIPPENDORFF, K. **Content Analysis**: An Introduction to Its Methodology (3a). Los Angeles: Sage Publications, 2013.

KUMAR, P.; REINITZ, H. W.; SIMUNOVIC, J.; SANDEEP, K. P.; FRANZON, P. D. Overview of RFID technology and its applications in the food industry. **Journal of Food Science**, v. 74, n. 8, 2009.

KUMAR, S. A knowledge based reliability engineering approach to manage product safety and recalls. **Expert Systems with Applications**, v. 41, n. 11, p. 5323-5339, 2014.

KUMAR, S.; HEUSTIS, D.; GRAHAM, J. M. The future of traceability within the US food industry supply chain: A business case. **International Journal of Productivity and Performance Management**, v. 64, n. 1, p. 129-146, 2015.

LI, Z.; LIU, G.; LIU, L.; LAI, X; XU, G. IoT-based tracking and tracing platform for prepackaged food supply chain. **Industrial Management and Data Systems**, v. 117, n. 9, p. 1906–1916, 2017.

LIN, W.; HUANG, X.; FANG, H.; WANG, V.; HUA, Y.; WANG, J.; YIN, H.; YI, D.; YAU, L. Blockchain Technology in Current Agricultural Systems: From Techniques to Applications. **IEEE Access**, v. 8, p. 143920–143937, 2020.

MEDEDJEL, M.; BELALEM, G.; NEKI, A. Towards a traceability system based on cloud and fog computing. **Multiagent and Grid Systems**, v. 13, n. 1, p. 47–68, 2017.

MONDAL, S.; WIJEWARDENA, K. P.; KARUPPUSWAMI, S.; KRITI, N.; KUMAR, D.; CHAHAL, P. Blockchain inspired RFID-based information architecture for food supply chain. **IEEE Internet of Things Journal**, v. 6, n. 3, p. 5803–5813, 2019.

PARRENO-MARCHANTE, A.; ALVAREZ-MELCON, A.; TREBAR, M.; FILIPPIN, P. Advanced traceability system in aquaculture supply chain. **Journal of Food Engineering**, v. 122, n. 1, p. 99–109, 2014.

PEREIRA, C. R.; CHRISTOPHER, M.; SILVA, A. L. Achieving supply chain resilience: the role of procurement. **Supply Chain Management: an international journal**, v. 19, n. 5/6, p. 626-642, 2014.

PIRAMUTHU, S.; FARAHANI, P.; GRUNOW, M. RFID-generated traceability for contaminated product recall in perishable food supply networks. **European Journal of Operational Research**, v. 225, n. 2, p. 253–262, 2013.

POTTER, A.; JASON, M.; LAWSON B.; GRAHAM, S. Trends in product recalls within the agri-food industry: Empirical evidence from the USA, UK and the Republic of Ireland. **Trends in food science & technology**, v. 28, n. 2, p. 77-86, 2012.

São Paulo State Consumer Protection and Defense Program (PROCON-SP). **Recall files from 2004 to 2020.** Available at: < http://sistemas.procon.sp.gov.br/recall/menu2/menu.php?texto >. Accessed on: 10 Sep. 2021.

PURWANDOKO, P. B.; SEMINAR, K. B.; S.; S. Development of a smart traceability system for the rice agroindustry supply chain in Indonesia. **Information (Switzerland)**, v. 10, n. 10, 2019.

QDA MINER. **Qualitative data analysis software**. Available at: <http://provalisresearch.com/products/qualitative-data-analysis-software/qda-miner-features/>. Accessed on: 29 Jul. 2021.

RATHORE, R.; THAKKAR, J. J.; JHA, J. K. A quantitative risk assessment methodology and evaluation of food supply chain. **The International Journal of Logistics Management**, v. 28, n. 4, p. 1272-1293, 2017.

REGATTIERI, A.; GAMBERI, M.; MANZINI, R. Traceability of food products: General framework and experimental evidence. **Journal of food engineering**, v. 81, n. 2, p. 347-356, 2007.

RINGSBERG, H. Perspectives on food traceability: a systematic literature review. **Supply Chain Management: An International Journal**, v. 19, p. 558-576, 2014.

RINGSBERG, H. A.; MIRZABEIKI, V. Effects on logistic operations from RFID- and EPCIS-enabled traceability. **British Food Journal**, v. 116, n. 1, p. 104–124, 2014.

RODRIGUES, D.; TEIXEIRA, R.; SHOCKLEY, J. Inspection agency monitoring of food safety in an emerging economy: A multilevel analysis of Brazil's beef production industry. **International Journal of Production Economics**, v. 214, p. 1-16, 2019.

RONG, A.; GRUNOW, M. A methodology for controlling dispersion in food production and distribution. **OR Spectrum**, v. 32, n. 4, p. 957–978, 2010.

SALAH, K.; NIZAMUDDIN, N; JAYARAMAN, R.; OMAR, M. Blockchain-Based Soybean Traceability in Agricultural Supply Chain. **IEEE Access**, v. 7, p. 73295–73305, 2019.

SCHOLTEN, K.; SCOTT, P. S.; FYNES, B. Building routines for non-routine events: supply chain resilience learning mechanisms and their antecedents. **Supply Chain Management: An International Journal**, 2019.

SKILTON, P. F.; ROBINSON, J. L. Traceability and normal accident theory: How does supply network complexity influence the traceability of adverse events? **Journal of Supply Chain Management**, v. 45, n. 3, p. 40–53, 2009.

STOROY, J.; THAKUR, M.; OLSEN, P. The TraceFood Framework–Principles and guidelines for implementing traceability in food value chains. **Journal of food engineering**, v. 115, n. 1, p. 41-48, 2013.

TANG, Q.; LI, J.; SUN, M.; LV, J.; GAI, R.; MEI, L.; XU, L. Food traceability systems in China: The current status of and future perspectives on food supply chain databases, legal support, and technological research and support for food safety regulation. **BioScience Trends**, v. 9, n. 1, p. 7–15, 2015.

THAKUR, M.; FORÅS, E. EPCIS based online temperature monitoring and traceability in a cold meat chain. **Computers and Electronics in Agriculture**, v. 117, p. 22–30, 2015.

THAKUR, M.; MARTENS, B. J.; HURBURGH, C. R. Data modeling to facilitate internal traceability at a grain elevator. **Computers and Electronics in Agriculture**, v. 75, n. 2, p. 327–336, 2011.

TRANFIELD, D.; DENYER D.; SMART, P. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. **British Journal of Management**, v.14, p.207-222, 2003.

TSANG, Y. P.; CHOY, K. L.; WU, C. H.; HO, G. T. S.; LAM, H. Y. Blockchain-Driven IoT for Food Traceability with an Integrated Consensus Mechanism. **IEEE Access**, v. 7, p. 129000–129017, 2019.

WANG, J.; YUE, H.; ZHOU, Z. An improved traceability system for food quality assurance and evaluation based on fuzzy classification and neural network. **Food Control**, v. 79, p. 363–370, 2017.

WANG, X.; LI, D.; LI, L. Adding value of food traceability to the business: A supply chain management approach. **International Journal of Services Operations and Informatics**, v. 4, n. 3, p. 232–257, 2009.

WOGNUM, P. M.; BREMMERS, H.; TRIENEKENS, J. H.; VORST, J. G. A. J.; BLOEMHOF, J. M. Systems for sustainability and transparency of food supply chains - Current status and challenges. **Advanced Engineering Informatics**, v. 25, n. 1, p. 65–76, 2011.

ZOU, Z.; CHEN, Q.; UYSAL, I.; ZHENG, L. Radio frequency identification enabled wireless sensing for intelligent food logistics. **Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences**, v. 372, n. 2017, 2014.