TRACEABILITY IN FOOD SUPPLY CHAIN: A THEORETICAL MODEL FOR THE IMPROVEMENT OF FOOD SAFETY

TRAZABILIDAD EN LA CADENA DE SUMINISTRO DE ALIMENTOS: UN MODELO TEÓRICO PARA LA MEJORA DE LA SEGURIDAD ALIMENTARIA

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KEYWORDS:
Traceability, food supply chain, food safety, food traceability, traceability in food supply chain.

Abstract

Traceability ensures food safety throughout the food supply chain through its application from obtaining the raw material to point of sale. In this sense, the study of traceability has aroused much interest in researchers. Consequently, this article carries out an exhaustive literature review where research on traceability in the food supply chain is analyzed in depth, which allows identifying their potential and shortcomings. Based on the analysis carried out, one hundred five (105) articles have been identified that highlight the potential for traceability in the food supply chain present in three (3) economic sectors: (1) agriculture and livestock, (2) fishing and (3) manufacturing industry. The results show that the study of traceability in the food supply chain was born nineteen years ago. The last 8 years, research has increased by 85% demonstrating that more research is being developed on the subject. Finally, in order to guide future research, the existing studies were analyzed with the purpose of knowing how traceability in the supply chain and its relationship with improving food safety has been addressed within the literature, identifying that the existing literature has analyzed only the traceability in some links of the supply chain or presents theoretical approaches. In this direction, based on our results we present a theoretical model oriented to measure the relationship between traceability throughout the supply chain and the improvement of food security, which constitutes a roadmap for future research aimed at knowing the relationship of traceability throughout the supply chain.

PALABRAS CLAVE:
Trazabilidad, cadena de suministro de alimentos, seguridad alimentaria, trazabilidad alimentaria, trazabilidad en la cadena de suministro.

Resumen

La trazabilidad garantiza la seguridad alimentaria en toda la cadena de suministro de alimentos a través de su aplicación desde la obtención de la materia prima hasta el punto de venta. En este sentido, el estudio de la trazabilidad ha despertado mucho interés en los investigadores. En consecuencia, este artículo lleva a cabo una revisión exhaustiva de la literatura donde se analiza en profundidad la investigación sobre la trazabilidad en la cadena de suministro de alimentos, lo que permite identificar su potencial y sus deficiencias. Con base en el análisis realizado, se han identificado ciento cinco (105) artículos que destacan el potencial de trazabilidad en la cadena de suministro de alimentos presente en tres (3) sectores económicos: (1) agricultura y ganadería, (2) pesca y (3) industria manufacturera. Los resultados muestran que el estudio de la trazabilidad en la cadena de suministro de alimentos nació hace diecinueve años. Los últimos 8 años, la investigación ha aumentado en un 85%, lo que demuestra que se está desarrollando más investigación sobre el tema. Finalmente, para guiar la investigación futura, los estudios existentes se analizaron con el propósito de saber cómo se ha abordado la trazabilidad en la cadena de suministro y su relación con la mejora de la seguridad alimentaria en la literatura, identificando que la literatura existente solo ha analizado la trazabilidad en algunos eslabones de la cadena de suministro o presenta enfoques teóricos. En esta dirección, en base a nuestros resultados, presentamos un modelo teórico orientado a medir la relación entre la trazabilidad a lo largo de la cadena de suministro y la mejora de la seguridad alimentaria, que constituye una hoja de ruta para futuras investigaciones destinadas a conocer la relación de trazabilidad a lo largo de la cadena de suministro.

INTRODUCTION

Due to the crisis in the last few decades related to food, people have been concerned about the optimal conditions that must be provided in the processes that involves from farm to table to ensure food safety (Rodríguez Ramírez et al., 2010). In this regard, the European Union (EU) reinforces the individual identification and traceability of food through the Regulation No. 870/97 of 1998 (Pavon, 2011). As per (Folinas et al., 2006), this regulation of EU is clear, but they consider that at the time of implementing the traceability system there is no specific methodology that describes the steps that need to be followed by companies in the food sector. As a result, different standards of traceability have emerged

for products (fruits, vegetables, meat, and others) aligned to improve the comprehension of different mechanisms to choose the rules and systems that carry out the implementation of the traceability in agri-food companies (Stranieri et al., 2017).

A good traceability system determines at which stage and when an error occurred in the process (Alfaro & Rábade, 2009). Furthermore, when speaking of food safety, it helps to build trust and establish long-term relationships between the supply chain partners and consumers. On the other hand, Swaroop et al. (2010) considered that traceability is an effective system for monitoring the safety and quality aimed to improve the safety of agri-food chain, which can generate confidence in food safety and consumer protection; therefore, consumers need to be guaranteed the responsibilities of those who manufacture and distribute food products (Sameer Kumar, 2008).

For companies who offer highly innovative operations, it allows them to have a competitive advantage. By this way, a company can enrich the traceability with elements that go beyond contractual agreements or voluntary certification (Canavari et al., 2010); however, there are significant differences between a country's interest on pursuing the implementation of the traceability system, like occurs when counties seek to integrate sustainable development (Myae & Goddard, 2012).

Based on the above, traceability has gained importance throughout the supply chain because it ensures food security through its application from obtaining raw materials to point of sale. Firstly, on this article you will find an exhaustive review of the literature on traceability in supply chain that identifies their strengths and weaknesses. Secondly, a depth analysis is performed based on different research related to the frequency of publication, and methodologies used by economic sector in which they have implemented traceability.

Finally, to guide future research, some existing studies have been analyzed with the objective to understand how traceability has been approached in supply chain, and its relationship with the improvement of food safety. By this manner, a theoretical model is presented to measure the relationship that exists between traceability and the entire supply chain process, including food safety. It would be a great contribution to validate the theoretical models proposed by companies in different sectors such as: fishing, agriculture/livestock, and food industry, so the empty gaps of the literature in hand can be filled.

IMPORTANCE OF CHAIN TRACEABILITY FOOD SUPPLY

First, we must understand the concept of supply chain. Please keep in mind that there is no single definition that describes the concept; however, over the years various researchers have worked on the concept of supply chain. Gómez-Cedeño & Castán (2014) analyzed a set of definitions and suggests that the concept described by Mentzer et al. (2001), used as a reference in countless investigations due to its clarity and robustness that establishes: "A set of three or more entities (organizations or individuals) directly involved in the downstream and upstream flows of goods, services, finance and information from primary source of production to the final customer. " This is why we consider that this definition is complete because it defines supply chain that has a competitive advantage through the efficient management of processes that can be used to improve the safety of food from the primary source of production till the final consumer. In this sense, to obtain a better understanding of the concept of traceability, an analysis was taken place based on existing definitions found within the literature (see Table 1).

Table 1

Definitions of Traceability per Author

	Definition	Author
1	ISO 9000: 2000 considers that traceability can face a nonconformity in a batch of products with the capacity to trace the root cause by identifying the batch of raw materials or parts used in manufacturing that could have caused the problem. Therefore, it is important to identify the state of inspection and test manufactured batches (As Non-conforming, Conforming), to ensure that only approved products are shipped or installed.	Barca (2002)
2	Locates traceability in a legal regulation context.	Hobbs (2004)
3	Traceability is defined as the ability of tracking and tracing in which it is possible to identify the initial source, the actual location, or the destination of any product from any stage in the supply network.	Fritz & Schiefer (2008)
4	They emphasize the problems of traceability in food by bacteria originated in the process, by the mismanagement of product refrigeration, or by using raw materials of poor quality.	Kehagia et al. (2017)
5	States that for traceability systems, record keeping is designed to track the flow of products or product attributes through the production process or supply chain.	Golan et al. (2004)

Based on the analysis and for purposes of this paper, we consider that the most comprehensive definition is raised by Fritz & Schiefer (2008): "Therefore, we emphasize that the implementation of traceability systems is essential to locate and identify the presence of error in processes throughout the supply chain.

On the other hand, the lack of traceability systems in the processes of the supply chain generates economic losses, so it is important to implement traceability systems that allow monitoring and control along the supply chain to guarantee quality assurance of the processes. It is also essential to consider the type of product based on the economic sector in which traceability systems are implemented because some considerations must be taken place to ensure its success.

ANALYSIS OF PUBLICATIONS BASED ON TRACEABILITY IN THE FOOD SUPPLY CHAIN

To understand the evolution of research on traceability in the food supply chain, a thorough review of literature is performed where it analyzes in depth research with the sole purpose to identify their potential and shortcomings. Hence, a systematic search was conducted in four databases: (1) ProQuest, (2) Emerald (3) Wiley Online Library and (4) Science Direct. During the process of research some keywords were used such as: traceability, food chain, and food supply chain. As a result, these words were found in titles, abstracts, and keywords. The search focused on publications between 1998 and 2020. Thus, 105 articles related to traceability and food supply chain were identified.

From the results, an analysis based on the frequency of publications on the subject was conducted, and we identified that the publications were conducted between 1998 and 2020, showing a 22-year period of studies. Additionally, it is important to highlight that in the last eight years, an increase of 85% of publications (see Figure 1) was recorded, which shows an increase of interest in the scientific community about the role traceability in food supply chain.

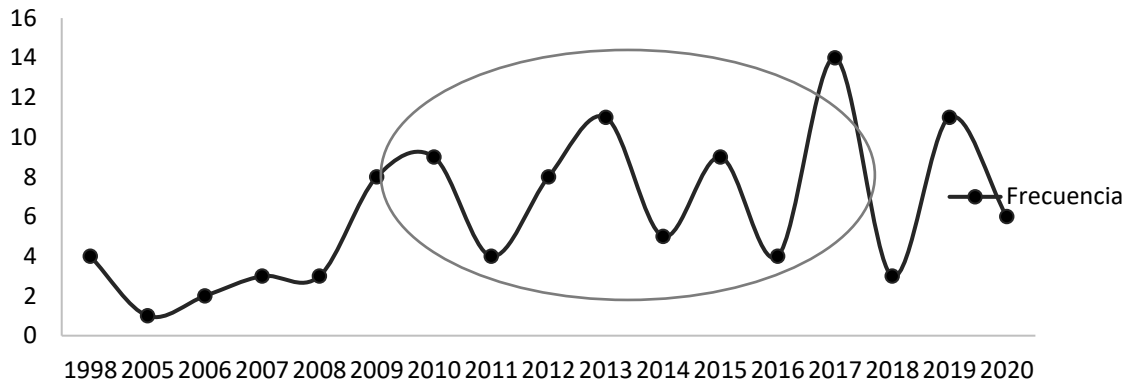

***Figure* 1.** *Frequency of Publication Related to Traceability in Food Supply Chain*

Also, a classification was made according to the type of method (empirical[1] versus non-empirical[2]) used in the articles identified. Thus, it was observed that 53% of the articles used empirical methods, and within this rate 32% of the articles used applications and software; whereas 47% of the articles used non-empirical methods, and within this rate 33% of the articles were based on theoretical concepts (Figure 2). With these results, it is perceived that a solid theoretical basis for the analysis of traceability in the food supply chain has not yet been developed.

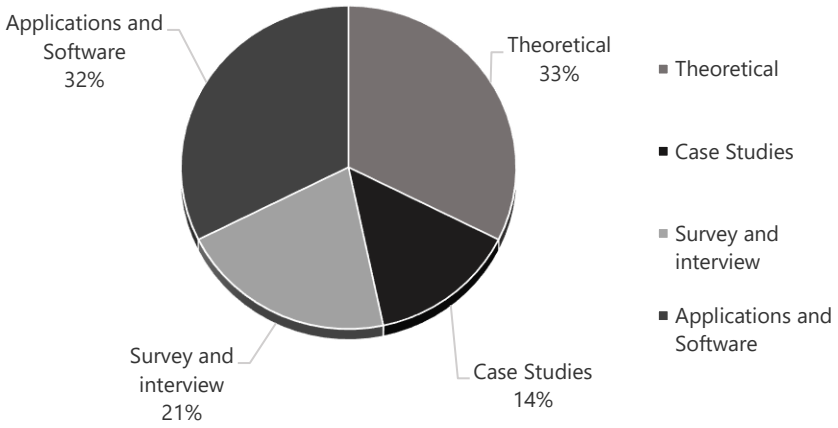

***Figure* 2.** *Classification by Type of Method (empirical vs. non-empirical) Used in the Articles Identified*

1The classification was made according Giunipero et al. (2008) where it considers how empirical methods: survey and simulation models.

2The classification was made according Giunipero et al. (2008) where considered non-empirical methods: case analysis and theoretical.

On the other hand, to find out where research have been directed on traceability in food supply chain by economic sectors[3], we grouped and classified one hundred five (105) articles by sector. The results show that 62% of the studies have mostly been oriented on food manufacturing industry, followed by 26% on agriculture and livestock, and finally 12% of the studies on fishing (see Figure 3). Thus, it is evident how investigations have gravitated towards one specific sector and leaves large gaps on others, and the main the reason why this occurs is because the food manufacturing industry has presented multiple cases of product contamination caused by various reasons; as a result, this has forced entrepreneurs to implement traceability as a measure of process control.

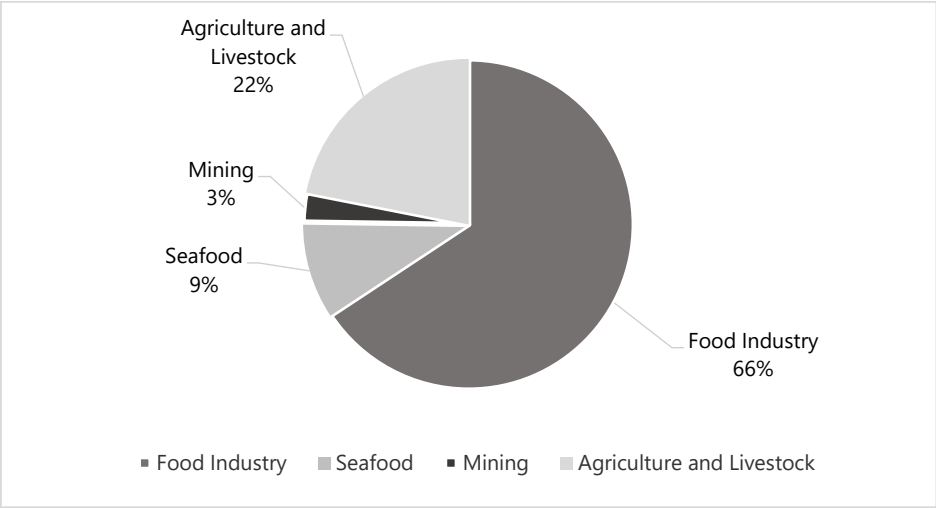

Figure 3. *Classification of Research on Traceability in Food Supply Chain per Economic Sector.*

In order to identify the main contributions, a content analysis of articles is performed based on each economic sector. Table 2 presents some highlights on the investigations identified during this analysis.

3 Classification of economic sectors was conducted based on the activities used in the calculation of gross domestic product (GDP) according to the National Institute of Statistics and Census (1996).

Economic Sector	Authors	Major Contributions
Food Industry	Swaroop et al. (2010)	They established that traceability is an effective system for monitoring the safety and quality in food chains with the sole purpose to increase consumers' confidence in food safety and consumer protection. However, the results underlined the need for further improvement, particularly in the definition of traceability in the food chain, application of regulations, and harmonization of practice
	Azuara et al. (2012)	They consider that economically and technologically the detection of counterfeit products has improved in the supply chain thanks to an inexpensive and scalable system based on radio frequency identification (RFID)
	Dandage et al. (2017)	They concluded that an effective system of food traceability is not only an important tool for managing food quality and safety risks, but also to promote the development of effective management of the supply chain
	Wang et al.(2009)	They noted that the management of the supply chain is influenced by traceability which in this case is considered fully integrated in the chain management and cannot be handled separately.
Seafood	Xinqing et al. (2014)	They obtained a requirement of traceability that evolved from a model against firefighting to a proactive model to improve the capacity of management of food safety processes.
Agriculture and Livestock	Manikas (2010)	They considered that proper labeling automation with the implementation of machine-readable labeling technologies, and the introduction of web-based technologies as a low-cost solution can improve the traceability of fresh products and logistics efficiency

Table 2. Major Contributions per Economic Sector

It is important to note that the major contributions in the literature are related to the manufacturing sector. As per Swaroop et al. (2010) there is a need to advance in the definition of traceability in the food chain. Furthermore, Wang et al. (2009) concluded that traceability should be developed along the supply chain which must be fully integrated and not handled separately. It is important to note that there is a need for progress when defining the concept of traceability, since the definition of an integrated traceability along the supply chain has not been conceptualize.

Table 3. *Articles About the Importance and Benefits of Traceability in Food Supply Chain*

Description	Zhao & Chen (2012)	Ringsberg (2014)	Lee et al. (2013)
Title	The Willingness of Farmers to Participate in Traceability Systems of Food: Improving the Level of Food Security.	Perspectives on Food Traceability: A Systematic Review of the Literature.	Application of TRIZ Marketing Model to Solve Operational Problems with Food Traceability Systems for Aquatic Products from Taiwan.
Purpose	Construct a theoretical model to explore the effect of incentives in a food traceability system to improve food safety standards.	Use food traceability as the means to identify the causes of deficiencies in supply chains.	Analyze and investigate the core operational problems using food traceability systems on aquatic products.
Economic Sector	Agriculture and Livestock	Food industry	Fishing

Methodology	Using descriptive statistics and a binary logistic regression model to investigate the factors that dominate the decision by farmers.	Perspective's analysis of risk- based approaches in the supply chain.	TRIZ theory to find the parameters for improvement and worsening of these problems.
Tool	Surveys (249)	Theoretical (129 articles)	Interviews
Analysis of the results	Increased effectiveness of food and traceability systems by the increase in payments to farmers to provide safe food. In addition, an increase in the fine imposed on suppliers for unsafe food are necessary conditions for improving food safety.	Eight perspectives on food traceability were identified and grouped based on the four approaches of SCRM: logistics management, information management, production management and quality management.	The findings of this study are threefold: seven central problems of aquatic products with food traceability systems were identified. Seven strategies to improve the marketing model were identified to solve operational problems of aquatic products with food traceability systems, and a new marketing model to solve operational problems was developed.

As shown in Table 3, the study by Lee et al. (2013)seeks reduce operational problems in the process of implementing traceability for seafood products. These findings can be used as a reference in other economic sectors. On the other hand, Ringsberg (2014) performed a literature review which has four theoretical perspectives aimed at improving the understanding of food traceability in the supply chain to ensure food safety. Despite this, the conclusions of this article are limited to the theoretical framework because it does not include an empirical evolution. Lastly, Zhao & Chen (2012) seeks to demonstrate that traceability systems can ensure food security, and they tested a theoretical model that measures the perception oriented on producers based on the importance of the traceability system and its implementation. As a result, they identified that producers have greater intention to implement traceability systems due to the greater profitability for its implementation and greater penalty for not guaranteeing the necessary measures to improve food safety; however, the study only analyzes one part of the supply chain, specifically the production stage and not the entire supply chain.

THEORETICAL MODEL TO IMPROVE FOOD SAFETY BY USING TRACEABILITY

Based on the above, we believe that there is much more to explore in terms of the relationship between traceability and improvement on food security because the existing

literature has analyzed only traceability in some links of supply chain or presents some theoretical approaches. In response to the gaps in the literatures found, we present a theoretical model oriented to measure the relationship between traceability throughout the supply chain and improving food safety (see Figure 4).

Figure 4. *Origin of the Proposed Model*

The proposed model seeks to measure the degree of participation or the producer's intention to implement the traceability system through the variables of need and willingness of the producers, the level of implementation of the traceability system through of the variables of information management, logistics management and production management, and the influence of improvement on operational problems along the entire supply chain by enabling food security through variables of food quality and safety requirements and monitoring of food characteristics, as shown in Figure 5.

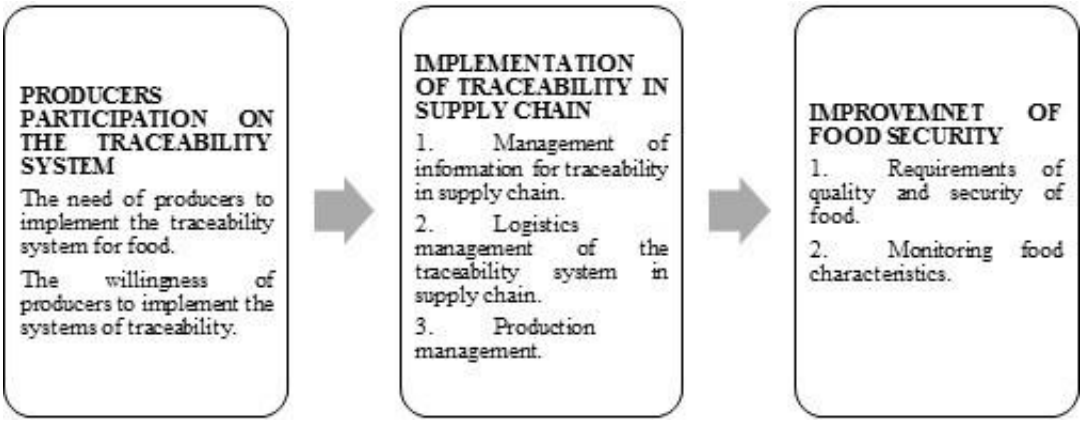

Figure 5. *Theoretical Model to Improve Food Safety by using Traceability.*

Source: Adapted from Zhao & Chen (2012) and Ringsberg (2014).

To do this, the studies of Zhao & Chen (2012) seeks the level of implementation of traceability systems along the supply chain that affect the improvement of food security, and Ringsberg (2014) takes into consideration the variables to measure the perception of

farmers. In Table 4, the description of factors and variables of the proposed model are presented.

Table 4. *Description of Factors and Variables of the Proposed Model*

Factors	Variables	Description
Producer participation in the traceability system	Producers need to implement traceability systems for food.	The need of a theoretical analysis on farmers to participate in food traceability system. Utility function represents decision-making for farmers on whether to join or not a food traceability system which depends on the contingent payment obtained and the costs incurred by participating in a food traceability system.
	Willingness of producers to implement traceability systems.	Household Characteristics: This group of factors consists in the age of farmers, level of education, income structure, and scale of production. Relative Behavior and Level of Consciousness: Behavior and knowledge are factors that denote if farmers have established good agricultural production practices, whether or not they have quality certification, and vehicle safety because they are concerned about the information on food quality and safety as well as awareness of traceability systems for food. Economic Factors: This group of factors includes the cost-benefit of vegetable planting, fines related to contaminated food, the expectation of traceable food prices, and expectations of risk involved in food traceability systems. External Factors: Finally, we want to discuss external factors such as cooperative behavior among farmers, participation in government subsidy programs, and technical training.
Implementation of traceability in supply chain	Information Management of traceability in the supply chain	Transparency: The need to elaborate contracts regulating the transparency and visibility in the exchange of traceability information. Strive to create strong relationships that facilitate risk-based visibility on information exchange for traceability.
	Logistics management of the traceability system in supply chain	Complexity in the Food Supply Chain: Managers of food companies must address food traceability based on the widespread integration of logistics and information systems. Unique Identification of Goods: Food supply chains should focus on the definition of traceability to ensure its guarantee on food and ingredients.

		They should consider using several or combinations of different identification techniques and global standardized numbers (eg GS1) to ensure unique identifications.
	Production management	In food production, it is important to consider implementing models to describe and visualize the interactions between production units and transportation. Also, it is essential to consider rule-based approaches to automatically establish relationships between production processes and implementation of traceability systems.
Improving food security	Requirements for quality and food safety.	Food Safety Management: Coordinated activities to direct or control food safety activities. Management systems for food safety: All documented procedures, practices, and operating procedures affecting food security. It comprises 3 levels: policy, practice, and registration forms. The systems should be based on programs with prerequisites and HACCP for the smaller and less developed businesses, so they can rely solely on the principles of HACCP or good hygiene practices. Involvement of Management: The extent to which managers / supervisors are involved in daily operations may affect food safety and how food handlers perceive their concern on food safety.
	Monitoring food security	Food Security Environment: The environment describes the structures and visible or discernible organizational processes that characterize the internal dimensions of companies. Norms: Measure values of hygiene practices compared to the legislations from United Kingdom (UK) or other standards and best practices. Type of Excellence: Taking in consideration whether the monitoring systems of food safety collect data that are useful for improving or maintaining hygiene of hands. Consistency Ensure that rules, training, and labor practices to understand food security priorities must be clear and achieved throughout the company. Perceived Organizational Support Different means of support (financial, practical, psychological, and emotional) that employees believe the organization is committed to food safety.

In this sense, it would be a great contribution to validate the theoretical model proposed for companies in various sectors such as Fisheries, Agriculture and Livestock, and Food Industry; as a result, this will allow to fill the existing gaps in the literature, and with the validated model a characterization of supply chains per food sector and identify the strengths and weaknesses of each sector can be made.

Hopefully, with this theoretical model, producers will be interested in implementing traceability systems, since currently in most cases the implementation of traceability systems is following the requirements imposed by the companies for their different suppliers.

CONCLUSION

The comprehensive analysis of studies has provided a framework to respond the question of how traceability in supply chain has been addressed in the literature and its relationship to improve food security. Based on this, we consider that the study of traceability along the supply chain presents a range of challenges and opportunities to raise future research. Despite the theoretical characteristics, this article is a solid theoretical base that can be used a roadmap for future investigations aiming to understand the relationship of traceability throughout the supply chain and, it is important to emphasize that it can be used and applied in various economic sectors.

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