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# Blockchain applied to the traceability of animal products: a systematic literature review[1]

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**ABSTRACT** - Blockchain technology, initially applied to the financial market, is recognized for its security in storing information in a decentralized manner and its ease of access to this information. An application of blockchain technology is the establishment of traceability systems for production chains. Food traceability systems are becoming increasingly important in guaranteeing the quality and safety of food to the final consumer, who, in turn, values and exercises confidence in the traceability system, recognizing its importance. This study was conducted to provide a systematic literature review on the importance of applying blockchain technology to the traceability of products of animal origin. Two scientific databases were consulted: Scopus and Web of Science. After classification based on the inclusion and exclusion criteria, 12 articles were selected for the study. The application of blockchain technology is recent, emerging, and promising in the traceability of animal products, and it has attracted research interest worldwide. The use of blockchain technology in the traceability of products of animal origin is used in several production chains, providing consumers with long-awaited information about the origin of their food such as beef, milk, fish, meat, pork, and eggs.

**Key words**: Agricultural supply chain. Food security. Animal production.

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## INTRODUCTION

Consumers are increasingly concerned about the origin and quality of food. This concern with information about the production process of consumed products has spurred the demand for traceability. Traceability is a set of techniques used to record information about a product's history, including data on the origin, treatments, and processes by which it was submitted (CORALLO *et al*., 2018). Concerns about food quality result in consumers being generally willing to pay more for food products of traceable origins (BADIA-MELIS; MISHRA; RUIZ-GARCÍA, 2015). Some consumers are interested in knowing the origin of the food, how it is obtained, the impacts generated during its processing, and, for foods of animal origin, if there was no occurrence of animal suffering and, primarily, if the products are safe for consumption (VITAL *et al*., 2018).

The complexity of supply chains often causes a lack of transparency in processes and traceability (MARTINS; LOPES, 2003). However, today, food safety is considered to be closely linked to public health. In recent decades, several foodborne epidemics involving animal products have been reported (HOCQUETTE *et al*., 2005; PRACHE *et al*., 2005). Governments and health organizations worldwide have established standards, laws, and regulations to eliminate incidents involving food of animal origin. For example, to satisfy the demand for traceability in the Brazilian bovine meat production chain, the Ministry of Agriculture, Livestock, and Supply (MAPA) created the Brazilian System of Identification and Certification of Bovine and Buffalo Origin (SISBOV) in 2002, enabling the tracking of cattle from birth to slaughter. The regulation of traceability has boosted the adoption of food safety measures by industries and producers, intending to minimize the damage caused to public health (HOCQUETTE *et al*., 2005).

Blockchain is a technology that has been adopted to track transactions and shared data, and it is used to secure and decentralize the storage of this information (NAKAMOTO, 2009). Blockchain technology has the potential to overcome severe deficiencies in the traceability process of production chains (GARG; KUMAR, 2021). Thus, the use of blockchain technology for the traceability of products can guarantee confidence in consumers, as it can enable clear access to all data records of a production chain. For producers, adopting traceability techniques adds value to their products (YIANNAS, 2018). For example, private companies in the food sector have invested heavily in adopting blockchain technology to achieve tracking in a short time with greater transparency and efficiency (WONG *et al*., 2020).

Blockchain technology has also been applied in the field of sustainable production to track and validate data on the carbon footprint traceability of products or companies. For this type of application, blockchain has advantages over other types of traceability because of its ability to manage large amounts of data (JU *et al*., 2022). With the implementation of traceability based on blockchain technology, information about entire productions has become simpler, more transparent, reliable, and secure for all components of a production chain. Therefore, this systematic literature review was conducted to address the importance of traceability of food products of agricultural origin based on the use of blockchain technology in production and marketing systems, and the implementation of this technology.

The remainder of this paper is organized as follows. Initially, the concepts and applications of animal traceability and blockchain are presented to provide the most important concepts for these subjects. Next, we describe the methodology used in this study. The results and discussion are then presented, followed by final considerations.

### FOOD TRACEABILITY

Traceability is a method of preventing the entry of products without the quality or safety necessary for a production chain. This requirement also facilitates the identification of steps outside the normal process and aids in the rapid implementation of containment measures and the attribution of responsibilities (CHAPAVAL; ALVES, 2008). A better quality of the tracking system results in greater agility in identifying and solving safety and quality problems in a production chain (GOLAN *et al*., 2004).

Various researchers have proposed structures and models to address the complexity of traceability in the food production chain. Regattieri, Gamberi and Manzini (2007) presented a traceability system that uses a radiofrequency identification code to track cheese. Shanahan *et al.* (2009) developed a traceability system that uses radiofrequency with biometric identifiers to track the pre-slaughter supply chain. Folinas, Manikas and Manos (2006) developed a real-time mobile application to track fresh, unprocessed animal foods.

Although many models and structures for food traceability are available, the rate of implementation in production chains is still relatively low because these traceability systems are dependent on a database for the storage and checking of information. Digital databases for traceability incur implementation, operation, and maintenance costs, which require financial investment and skilled labor (KARIPPACHERIL; RIOS; SRIVASTAVA, 2017). In addition, the credibility of traceability can be reduced if the information storage system is centralized, which restricts full transparency (SCHOLTEN *et al*., 2016). In contrast to conventional data recording methods that have centralized management, exposing data related to the production chain to the risk of violation, and high implementation costs, blockchain technology can be used to track food products and store information in an easier, faster, and safer manner at a lower cost (YIANNAS, 2018).

Currently, consumers demand transparency, reliability, and traceability of information regarding the production chain and consider traceability as a sustainability attribute (BURNIER; SPERS; BARCELLOS, 2021). For example, beef traceability is highly valued by consumers because it is essential to know the origin of the animal and the transformation processes that occur along the production chain (LOUREIRO; UMBERGER, 2007). This indicates that the degree of adoption of traceability systems in food production chains is increasing.

## BLOCKCHAIN

Blockchain is a shared digital database system in which data are interconnected to form a chain. In this system, every transaction between two participants is permanently registered on the blockchain; these records are called blocks, and each computational machine used for blockchain processing is called a node. Each block has predefined characteristics and a unique code called a hash. The hash is responsible for communication between blocks, in addition to connecting the block to its preceding and next blocks, thus forming a chain of blocks (GARG; KUMAR, 2021). Therefore, modifying the blockchain data requires that the hash code must be changed. This demands significant operational effort, which requires time and a high processing capacity. Thus, data tampering becomes unfeasible, making the blockchain an immutable database (MONFARED, 2016). Unlike conventional database systems, a blockchain has no central authority that controls the system, and all members of the network have equal authority (MONFARED, 2016).

Different types of blockchains are available: public, private, and hybrid, categorized based on the users accessing the technology. The difference between them lies in the permission granted for access. In the public blockchain, anyone can access the network. This type is important for corporate use cases; an example of this type is Bitcoin. In a private blockchain, network access control is based on established permissions. The hybrid blockchain is managed such that some information and permissions are restricted to certain participants; thus, is commonly used (GARG; KUMAR, 2021). Both private and public blockchains have structures for applications in different branches (YANG *et al*., 2020). The architecture of a blockchain system is based on the concept of a smart contract, which is an agreement between the parties involved in the process in which the governance, information flow, and trust between the parties involved are established.

Blockchain implementation is typically based on five principles that underlie the technology (BROPHY, 2020): I) distributed databases, in which a copy of the data is stored in each node of the blockchain; II) point-to-point transmission, in which each network user stores and transmits information directly to the entire network, without requiring intermediaries; III) transparency, in which every transaction is visible to any member who has access to the network; IV) irreversibility of records, in which after storage the data cannot be changed; V) computer programming, which facilitates future applications of the data (XIE *et al*., 2018).

Blockchain enables the traceability of an entire production chain, including the easy incorporation of regulatory bodies for the certification of processes (SHINGH *et al*., 2020). Its use is increasing in private institutions in the food sector, functioning as a tool to facilitate logistics tracking. Therefore, several companies are beginning to involve blockchain technology in their production chains, such as the Walmart Organization in tracking pork products, McDonald's in tracking eggs, and Nestlé and JBS in tracking produced food (KSHETRI, 2018).

Creydt and Fischer (2019) revealed the transformative potential of blockchain in overcoming challenges such as the lack of transparency and full traceability of many production chains. Hua *et al*. (2018) suggested the use of blockchain in food traceability and the recording of operations throughout a production chain, including agricultural production chains, positively impacts profitability (CHANG; IAKOVOU; SHI, 2020). However, despite the significant potential of blockchain technology and the increasing use of private initiatives, few applications for agricultural use have been recorded in the literature.

# MATERIAL AND METHODS

This systematic literature review was conducted to investigate the following questions. How is blockchain technology used in the traceability of food products of animal origin? Which production chains report blockchain technology applications? What is the importance of blockchain technology for foods of animal origin? A technical variation of the problem, intervention, comparison, and outcome (PICO) method was used (ERIKSEN; FRANDSEN, 2018). This systematic review focused on the chain of products of animal origin to establish the usability of blockchain technology in this area.

The criteria for the inclusion of the articles to be analyzed were as follows: (1) the study must be published in English and present the application of blockchain technology under the traceability of products of animal origin of any kind. (2) The article should include scientific

**Table 1** - Total number of articles and number of articles selected according to the search performed with the two descriptors

| Descriptors | Total number of articles | Selected articles |
|---|---|---|
| ((blockchain) AND (traceability) AND (animal products)) | 22 | 7 |
| ((blockchain) AND (food)) | 322 | 12 |

research and/or the development of technology; thus, publications on bibliographic reviews were excluded. (3) The publications should include the chain of products of animal origin. The year of publication was not adopted as a criterion in the search for studies because blockchain is a recent technology.

The search for scientific articles was conducted in October 2022. Articles were obtained electronically from two databases, Scopus and Web of Science, covering four areas of research: agricultural sciences, animal production, food technology, and information technology. Subsequently, a complementary search was performed to include documents that were not found in the primary search. Two descriptors were used for the bibliographic search: ((blockchain) AND (traceability) AND (animal products)) and ((blockchain) AND (food)). The results of this bibliographic search are presented in Table 1, which shows the total number of articles included in the search, and the number of articles selected based on the inclusion and exclusion criteria.

For this study, the descriptor ((blockchain) AND (food)) was selected because it provided the highest number of articles, as listed in Table 1. The search process using this descriptor yielded 322 articles, which were filtered based on the exclusion criteria. A total of 12 articles were selected for this study. Of the rejected articles based on the exclusion criteria, 58.33% were publications of bibliographic review type and 41.67% were publications not regarding blockchain applications in the animal-origin production chain. Duplicate publications were identified and excluded. To answer the research questions, we extracted basic information that contained the title of the publication, authors' names, country, and year of publication, and information related to the article that included the objectives, blockchain application, tracked production chain, and results obtained.

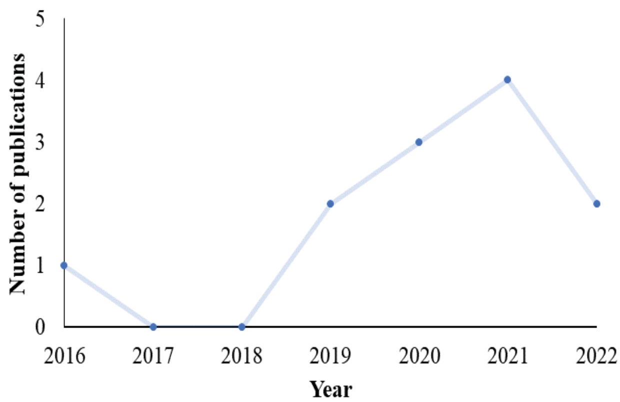
## RESULTS AND DISCUSSION

The number of publications per year of the selected articles is shown in Figure 1. 2016 was the first year with a publication on blockchain applied to the animal production chain. This proves that the use of blockchain technology in this area is relatively recent. An increase in the number of publications over the years was observed, indicating the emerging potential of blockchain technology for tracing products of animal origin. The decrease observed in 2022 was probably because the survey was completed before the end of that year.

The geographic distribution of the selected articles on the use of blockchain in the animal-origin food production chain is shown in Figure 2. The geographical distribution of the selected articles demonstrates that blockchain technology in the field of traceability of animal-product production chains has attracted research interest in many countries. Figure 3 shows the distribution of animal products tracked via the blockchain in the selected articles. Beef was discussed in 42% of the selected articles, followed by milk (34%), fish (8%), pork (8%), and eggs (8%).

Table 2 lists the selected articles, their respective authors, objectives, and the production chain in which the blockchain technology was applied. This verifies that blockchain technology has been used in research on the traceability of various food products of animal origin such as milk, eggs, fish, pork, and beef. The publications listed in Table 2 show that blockchain technology is adopted owing to its credibility and security, as production chains always seek a safe, complete, and reliable traceability system. Blockchain technology increases consumer trust

**Figure 1** - Number of publications selected per year on the use of blockchain on the animal-origin food production chain



in tracked products (PAPA, 2017). In addition, it provides the possibility of covering the entire production chain, satisfying the objective of the research that intends to integrate all parts of the chain as well as the final consumer.

**Figure 2** - Geographic distribution of selected articles on the use of blockchain in the animal-origin food production chain

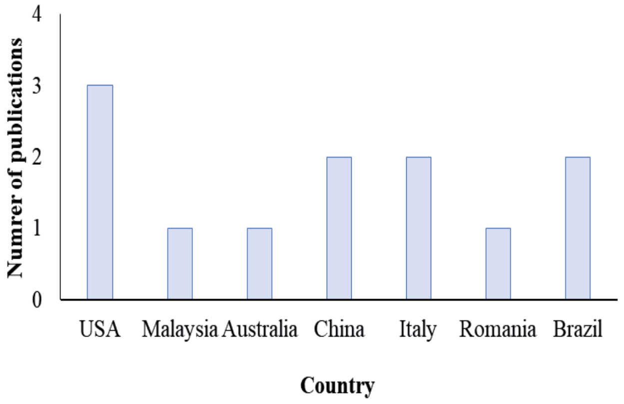



**Figure 3** - Percentages of animal origin products tracked using blockchain in the selected articles

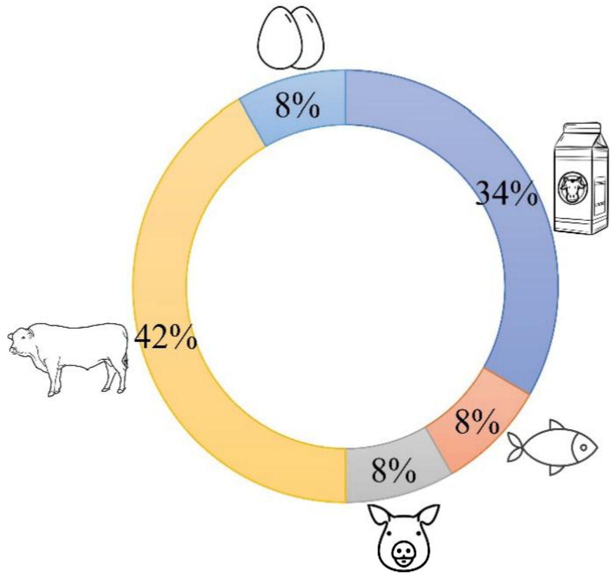



**Table 2** - List of selected articles, detailing authors, research objective, and productive chain tracked with a blockchain application

| ID | Authors and Year | Productive Chain | Research Objective |
|---|---|---|---|
| 1 | Hackett (2016) | Pork | To track the origin of a product for food safety and to add value to the product. |
| 2 | Tradigo *et al*. (2019) | Milk | To develop, based on blockchain, a system capable of monitoring and tracking the entire production chain of agricultural products, and applying it to the milk production chain. |
| 3 | Marin, Marin and Vidu (2019) | Milk | To create a blockchain platform to indicate the origin of milk to consumers, providing information on animal management and health, processing, and transport of the product. |
| 4 | Du *et al*. (2020) | Fish | To optimize a blockchain-based traceability system and implement this system in the fish production chain, strengthening the reliability of the information. |
| 5 | Bumblauskas *et al*. (2020) | Eggs | To create a platform for viewing the origin of the product, based on blockchain technology. |
| 6 | Mendonça *et al*. (2020) | Milk | To develop an architecture to track the milk production chain via blockchain to store and validate the data collected at the various product control points. |
| 7 | Mazzù *et al*. (2021) | Milk | To evaluate the perception of milk consumers when receiving tracked information via blockchain. |
| 8 | Nadhirah Hamidi *et al*. (2021) | Beef | To propose the use of blockchain in the beef supply chain to seek transparency throughout the production process. |
| 9 | Cao *et al*. (2021) | Beef | To strengthen trade between two countries with complete tracking of the production chain, based on a blockchain application. |
| 10 | Felippe and Demanboro (2021) | Beef | To develop a blockchain application applied to tracking the entire beef production chain. |
| 11 | Lin *et al*. (2022) | Beef | To evaluate the demand for tracked beef via an application based on blockchain technology. |
| 12 | Shew *et al*. (2022) | Beef | To evaluate on an experimental scale a blockchain application implemented in the beef production chain. |

Some of the selected articles were unclear on whether a blockchain platform was used to develop each application. Four research articles reported the use of the Ethereum platform, which is a public platform. Three articles reported the use of a private HyperLead platform, which is private. Based on this information, Ethereum and HyperLead platforms are more common in the development of blockchain applications. This may be because they are consolidated and well-established platforms in the market for this purpose (FELIPPE; DEMANBORO, 2021).

## FINAL CONSIDERATIONS

Based on the articles selected in this systematic literature review, the use of blockchain technology in food traceability has been gradually adopted by the animal production sector since 2016, aiming at the integrity of stored data and agility in querying them, thus satisfying the concern of consumers regarding the origin of their food. Blockchain technology is used in several countries and exhibits potential in the field of traceability of products of animal origin, even under the high complexity of the sector's production chains, as it can completely encompass the chain safely and with clear information. Beef was the most-tracked product, followed by milk, eggs, fish, and pork. In most selected articles, the platforms Ethereum and HyperLead were used in blockchain applications for product traceability. Blockchain technology is useful for various objectives. However, despite its significant potential and importance, few studies have demonstrated its applicability in the production chain of animal products.

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