

Martínez-Castañeda, Mónica; Feijoo, Claudio

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## Challenges in data management in the agri-food industry. A systematic comparison of permissioned blockchain- based IT business applications

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# **Paper for the 32nd European regional conference of the International Telecommunications Society.**

## **AUTOR:**

**Mónica Martínez-Castañeda.**

**Claudio Feijoo.**

## **TITLE**

**Challenges in data management in the agri-food industry. A systematic comparison of permissioned blockchain-based IT business applications.**

## **ABSTRACT**

This article includes a bibliographic study to identify, evaluate, and interpret existing research regarding the effectiveness of blockchain technology applications in the field of agricultural production condition accreditation. Drawing from the review, and to illustrate the technical architecture of the blockchain-based logistics tracking system, the article focuses on the management of raw data as a system parameter that will determine the advantages and limitations of existing business solutions. Additionally, considerations are incorporated into the system construction to reduce information asymmetry and increase the business power of producers when using public databases. Basically, the bibliographic compilation and analysis are aimed at improving two aspects: the veracity and relevance of the production data collected in the blockchain systems, and offering tentative handling methods that increase the producers' power of control over the systems by using data and verifications already completed for the administration for other purposes.

## **1. INTRODUCTION**

Blockchain technology was designed to provide a trusted and immutable record of events arising from a dynamic collection of untrusted parties. The evolution to authorized systems marked a first paradigm shift, since these restrict the people who can participate in the network. In these cases, there are one or more entities controlling the network and in practice third parties are relied on to carry out the transactions. However, if the system being developed deals with contractual relationships between participants, does not directly manage digital currencies, and there is no single operator that everyone trusts, a permissioned blockchain is a typical option (Marchesi et al. al., 2022). This is the case of blockchain-based applications that are used to certify food production conditions.

The success of permissioned systems has led to the proliferation of different token providers, blockchain-based platforms of varying sizes and reputations, as well as associated or derived software solutions. Meanwhile, lower volume platforms compete through various strategies such as vendor reputation and specialization. For example,

the "This Fish" directory of software<sup>1</sup>, blockchain and AI applications for the fishing sector offers more than twenty-eight blockchain-based solutions for traceability and more than a hundred without this technology. In addition, the Hyperledger Foundation website contains more than twenty food traceability solutions based on Hyperledger blockchain technologies. This situation makes the market for traceability technology saturated and confusing.

To provide traceability from farm to table, blockchain technology is combined with other technologies that enable more data to be stored in the system (databases or external services) or collected automatically (IoT)(Azzi et al., 2019).

In the token provider market, giants' platforms coexist with smaller solutions providing classification. An analysis of these providers can be made based on size or reputation, but what is most relevant is the evaluation of tokenization and its role in achieving the goal.

The common aspects of blockchain analysis are based on the fact that the most relevant information will remain unaltered and in a decentralized manner, but the guarantees of that information depend on two specific aspects: on the one hand, if the data captured and used are adequate to certify that information, and on the other, how the data is being stored. Regarding this second aspect, it is important to consider that, although the benefits of the blockchain that are included in many scientific articles (Mistry et al., 2020; Zhang et al., 2022; Kshetri, 2021) are based on the information, it is not stored in a specific datacentre, of the parent company, or of a certain technological company, but in the nodes that make up the chain of blocks. However, the amount of information stored in this way is quite limited, so the solutions applied to agri-food traceability will not be able to keep or store all the data necessary to offer all the information that the consumer finally demands and will depend on other internal and external processes external software solutions that are also part of the system. This aspect does not necessarily mean a defect if the design used is suitable to guarantee the desired objectives or the appropriate cross-control or verification measures are adopted.

At the present time regulatory gaps exist due to legal, technological, and operational specificities related to the use of distributed ledger technology and this blockchain system that qualify as "quality certificates". For instance, there are no transparency, reliability or safety requirements imposed on the protocols and 'smart contracts' that underpin that qualify as "certificates".

In this study, the system architecture is prioritized from the point of view of ensuring quality derived from data coming from primary production, not from other factors such as simplification, efficiency, cost automation, permanence, disintermediation. This is a critical success factor to implement BT in sustainable supply chain management(Saurabh & Dey, 2021; Zhang et al., 2022)

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<sup>1</sup> <https://this.fish/software-directory/>

To assess the veracity of the system, it is important to consider the role of the blockchain in the entire system, as well as to investigate the part of the information that is not stored on the blockchain, an issue known as "the oracle problem" (Al-Breiki et al., 2020).

The article proposes a compilation of evaluation parameters that allow us to analyse the advantages and limitations of existing commercial solutions in relation with data management, likewise considerations are incorporated into the construction of the system that must be considered from the legal point of view in the European context. The design of a suitable blockchain architecture for "industrial" applications that would manage contractual relationships between customers and industrial providers has been discussed in multiple papers, and also the evaluation framework based in several criteria (Marchesi et al., 2022a).

However, few studies have focused specifically on data source management for blockchain-based systems, with the aim of increasing the quality and security standards, as well as reducing the information asymmetry and amplifying the business power of producers. Authors like Susanne Köhler (Köhler & Pizzol, 2020) address the various technical limits that have yet to be resolved, including the limitations in using blockchain technology within eco-labeling schemes which cannot be replaced by external certification mechanisms, something that could possibly be attained by a system that can use data stored in the administration for other purposes.

#### **The research is designed as follows:**

- Study of the state-of-the-art of existing research concerning relevant parameters in current permissioned blockchain architectures used to certify food production conditions, with special attention to data management.
- Select the parameters that contribute to a more robust architecture in terms of pertinence, veracity, and data assurance in the chain, and suggest one or more basic management models that enhance raw materials production data veracity in blockchain systems intended to certify food production conditions.
- From the previous perspective, based on what points must be clarified by the operators to ensure that the blockchain architecture offers an adequate level of trust and control of the information. It is analysed which points can help with the reuse or iteration of the database system and official controls present in Europe in the improvement of the building of blockchain systems for use in the primary sector.

#### **Research questions:**

Face of a multiple scenario in the offer of applications and taking into account that agents wish or need to choose a decentralized management system based on blockchain, the following research questions are posed:

- **How to approach a comparative study of blockchain-based applications in the agri-food sector?**

- **What criteria should be considered when selecting a blockchain application in the agri-food sector based on data accuracy?**
- What are the distinguishing characteristics of different blockchain-based applications, particularly regarding data precision?
  - 1) Factors related to the method of data collection, for instance: pertinence and integrity<sup>2</sup>.**
  - 2) Factors related with handling data, for instance: security<sup>3</sup> Transparency<sup>4</sup> and verification mechanisms.**

Although all the elements that condition the blockchain, scalability and efficiency are also important factors to cover the data needs of the agri-food sector to allow a faster and cheaper process of data exchange, these factors will not be addressed in this study.

The investigation will serve to highlight the most relevant information about the management of data into the blockchain system architecture that is relevant and must be disclosed by the operators, to guarantee that the blockchain architecture provides an adequate level of trust.

Then and based on the result of previous research question an additional question is proposed:

**¿ Is there a way to provide potential management techniques to increase the producer's authority over systems using data and assessments already conducted for other administrative purposes?**

The paper creates some hypothesis of solution based of the knowledge of legal text collections.

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<sup>2</sup> The blockchain application should ensure the accuracy and completeness of data stored on the blockchain, preventing any manipulation of the data.

<sup>3</sup> Secure environment for data storage and transmission, preventing any unauthorized access or tampering with the data.

<sup>4</sup> The blockchain application should provide transparency in data sharing and access control, enabling all parties involved to verify and validate the data.

## 2. METHODOLOGY

This document conducts a systematic review of the literature to explore the latest academic research on the evaluation of permissioned blockchain systems. The guidelines provided by Kitchenham and Charters have been used ([Kitchenham, n.d.](#)), to develop the needs analysis and review plan methodology. The systematic approach proposed by these authors includes research questions, data sources used to retrieve articles, search strategy, inclusion and exclusion criteria and final selection and evaluation.

As a first step, this methodology performs a review of the specialized literature based on the three research questions defined previously, as used by other authors in equivalent research works ([Shuaib et al., 2022](#)). The review focusses on the management of data into the blockchain system architecture that is relevant and must be disclosed by the operators, to ensure that the blockchain architecture provides an adequate level of trust. Thus, the literature review will determine the characteristics of the data needed and provide recommendations for the data architecture best suited for the application.

Subsequently, the goal of the research is also to compile or generate ideas about how the information system for public authorities in Europe could contribute to the design and building of a more comprehensive data architecture in blockchain system applications. For this purpose, a corresponding legal study is conducted to identify actions that could be introduced or cross-checked with public controls done into the systems. A tentative use case is explained to illustrate this case.

### 2.1 Review

- Planning the Review:

To systematize the evaluation of commercial technological solutions based on blockchain and applied to the agri-food sector **which serves to certify production conditions** is necessary to identify previous studies on this matter and analyse the parameters used to evaluate the existing trust models.

Several authors ([Sunny et al., 2020a](#)) ([Marchesi et al., 2022b](#)) have already been studied the design of blockchain traceability solutions. Each use case is reviewed to understand the purpose of blockchain traceability in various contexts, limitations and advantages, and the methodology followed to develop the solution. Based on these previous studies this paper reviews the concepts published on blockchain based technology systems, by pointing out **for the certification of primary production conditions**, the identification of crucial or vulnerable parts in a blockchain architecture system with especial attention to data management: **data collection and handling**.

The purpose of the review is to know the status of blockchain technology applications in the field of accreditation of agricultural production conditions since 2019 using a tertiary study to review articles related to blockchain architecture analysis.

To identify and evaluate evidence from research studies, Systematic Literature Review (SLR) is used as the main method of synthesis. “To provide the means by which current best evidence from research can be integrated with practical experience in the decision-making process regarding the development and maintenance of software.”(Dybå & Dingsøy, 2008). In this context evidence is defined as a “synthesis of best quality scientific studies on a specific topic or research question. The main method of synthesis is a Systematic Literature Review”.

Specifying the research question:

The research questions look for assessing the project success of the technology concerning on connecting the physical characteristics of the product with the content of digital content save in the blockchain so the literature review is thus organized around the following three themes:

- The first research question (1) looks for papers that have being are being addressed the comparison of blockchain-based applications used in the agrifood sectors.

**How to approach a comparative study of permissioned blockchain-based applications in the agri-food sector?**

- The second research question (2) look for risk factors associated with the permissioned blockchain technology in the agrifood sector regarding data accuracy.

**What features should be considered to compare and choose one application or another of blockchain in the agri-food sector? (Features to compare permissioned block chain technology in the agrifood sector regarding data accuracy).**

- The third research question (3) is in fact a battery of questions concerning the evaluations of the different risk factors on permissioned blockchain architectures related to data collection:

**Factors related to the method of data collection: pertinence and integrity. (“data accuracy, data selection and permissioned blockchain and agri-food”)**

**Factors related with handling data: security<sup>5</sup> Transparency<sup>6</sup> and verification mechanisms. (“data, security, transparency, verification, permissioned blockchain, agri-food sector”)**

The additional question posed, is only used for selecting a case study to illustrate a model using official databases:

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<sup>5</sup> Secure environment for data storage and transmission, preventing any unauthorized access or tampering with the data.

<sup>6</sup> The blockchain application should provide transparency in data sharing and access control, enabling all parties involved to verify and validate the data.

In order to develop a case study a search has been developed among official legal repositories concerning mandatory provisions that establish **official data bases or data collection that we could use for this purpose.**

## 2.2 Search Process

**Part I:** The search process involved manually through specific scientific databases (mainly Science Direct), conference proceedings and journal papers from 2019 onwards. To mitigate bias, relevant researchers were consulted directly, as well as consulting conference abstracts related to the topic.

Sources:

SOURCE	RESULT (Number of papers per year per source)			
	2019	2020	2021	2022-2023
(Question 1) Science Direct 16 (includes:6)	3	5	2	6
(Question2) Science Direct 5 (includes: )	0	3	3	0
(Question 3.1) Science Direct 48(includes: )	3	5	3	10
(Question 3.2) Science Direct (includes: )	9	11	7	39
Conference Abstracts.			1	2

Specific researchers will also be contacted directly: Dr David Arroyo Guardado

**Inclusion Criteria:** Articles published from January 1st, 2019, to May 30th, 2023, on the topics of Systematic Literature Reviews (SLRs); literature surveys with defined research questions assessing the success of technology; data extraction; data presentation; and meta-analysis related to this topic will be included.

**Exclusion Criteria:** Papers that are informal literature surveys (without defined research questions, search process, defined data extraction or data analysis process), papers not subject to peer-review, papers discussing social aspects unrelated to technology issues or not related to the use of blockchain in supply chain, or articles appearing to be duplicates will be excluded.

Papers 'collection: selected papers will be classified as follow:

- The source (i.e., database, conference, or journal).
- The year when the paper was published.
- Classification of paper o Type:
  - (A) General Scope (Including systematic Literature Reviews).
  - (B) Metanalysis or identification of risk factors in general.
  - (C) Specific risk factors on permissioned blockchain architectures related to data collection:
- The author(s)
- Research issue.
- Quality score for the study (citations).



The result of the selection is presented in APPENDIX I.

The data has been extracted by one researcher and checked by another.

**Part II:** To develop this search, it was used previous searches already conducted in previous studies ([Martínez-Castañeda & Feijoo, 2023](#)). The regulation compilation selection had been contrasted and updated by using several legal data repositories: The search protocol followed was the following:

- scope of the search: mandatory provisions that establish official data bases or data collection.
- jurisdiction in which the search is to be conducted and type of government or other entity with authority over the official data bases or data collection: Food and agricultural provision in the European geographical region.
- legal repositories: BOE and VLex.
- relevant keywords: registry, database list, food and agriculture regulatory provisions, VLex repository offers a provisions compilation on control and on provisions related to political common agricultural policy.
- Analyze the results and identify any relevant mandatory provisions.

### 2.3 review protocol evaluation:

This research has conducted bibliographic searches in two parts to analyze the performance of blockchain technology in the agri-food value chain management:

For the second part, a search of legislation and official databases was conducted to identify potential management techniques to increase the producer's authority over systems using data and assessments. The result of the search was then compared with previous studies.

- In the first search, few papers were found that measure the performance from the perspective of the quality and relevance of the raw data utilized in the system and how it is stored. In addition, several literature review papers were found that explored how blockchain technology has been used to monitor food product quality. The result of the search concerning part I is presented in Appendix I.

In this bibliographic search of articles analyzing the performance of applying blockchain technology in the agri-food value chain management, few papers measure the performance from the perspective of the quality and relevance of the raw data utilized in the system and how it is stored. At the same time, several literature review papers have explored how blockchain technology has been used to monitor food product quality and provided insight into the development of blockchain technology in different industries.

- The results of the second part of the search are presented in APPENDIX II.

In response to the additional question posed, a search of legislation and official databases has been conducted to identify potential management techniques to increase the producer's authority over systems using data and assessments.

### 3. ANALYSIS

Most of the articles selected by the search show the benefits of blockchain as an efficient solution for IoT-based large scale data management systems(Dey & Shekhawat, 2021; Sezer et al., 2022) but the selection yielded a small sample of articles that analyzed the correct organization and handling of data within the system.

To collate and summarize the results of the bibliographic study focusing on the areas of data collection and data handling, the authors applied a qualitative content analysis approach (Levac et al., 2017). The analysis resulted in:

- (1) an overview of the critical variables of blockchain architecture regarding data collection and data handling reported in the literature and
- (2) an evaluation of the potential solutions presented by the authors for each variable, (providing a guidance towards potential solutions that could support those systems from the point of view of administration)

#### **3.1 Critical variables of blockchain regarding data collection directly involved in responses adequacy to the networking consensus.**

- **Data Entry (Capturing):**

Having a reliable data capturing procedure is key to validate the reliability of transactions and ensure the trust in the system as discussed in the reviews showed by several authors(Saurabh & Dey, 2021; Machado et al., 2020) Also, many authors have suggested the possibility of replacing manual data entry on the blockchain with an automated system via tamper-proof IoT devices that can directly certify data in the blockchain(Bayano-Tejero et al., 2019;Manning et al., 2022). However, this requires additional software and hardware equipment, which can lead to certain solution cost. Therefore, an optimal approach is needed to enable both accuracy and cost-efficiency.

In this sense, the same access or control of the system can be done by crosschecking with data presented in official databases and then recording transactions through a Smart Contract(Hewa et al., 2021). For example, the origin data of the farm within a Denomination of Origin can be entered by a farmer as long as the farm is registered in the name of that farmer. The amount of harvest registered in the said farm must also be within a specific range of parameters for the contract to be perfected.

- **Pertinence:**

Regarding the technical domain, the first challenge is posed by the "digital twin coherence" issue. What is tracked and certified through the blockchain is indeed a digital twin of the real world, but the extent to which the digital twin reflects the real world is difficult to guarantee. Verifying this aspect is closely linked to another data management factor "Data demanding", although very little detail is currently known about which information is and will be provided to end-consumers in the future. Data will thus be pertinent to the extent that it certifies the specifics aspects that the system is offering to the consumer. This aspect is especially important in control that products are labeled according to features of products at the point of purchase that it's possible to prove.

**3.2 Critical variables of blockchain regarding data handling directly involved in responses adequacy to the networking consensus. Literature review evidence some Vulnerability related to data handling; it has been selected the following parameters:**

- **Data storage**

Data storage can be a problem with blockchain-based technologies, both in terms of speed and costs. Therefore, many traceability projects use an external database to store the data, and only the hash of the data is placed on the blockchain itself. Access to, use of and security for the external databases linked to the blockchain have a big impact on the integrity, transparency, and control of the data in the system. To maintain a decentralized system, decentralized databases can be used, such as the Inter Planetary File System, a decentralized database for storing files. TE-Food and FairChain also store data off-chain ((Köhler & Pizzol, 2020) Decentralization is often seen as a data storage security measure to prevent a 'single point of failure', thereby promoting the decentralization of power and information. Nevertheless, decentralization is a complicated aspect, as it depends on the blockchain configuration, and the roles attributed to the blockchain participants.

The setup of the data storage affects the privacy of the data, as the information stored off-chain may not be as easily accessible. Additionally, a smaller amount of data needs to be conveyed on-chain, which has a positive effect on the speed and cost of blockchain-based technologies. Furthermore, decentralization should consider all members of the system, including those with fewer resources (Zhao et al., 2019).

Like the off-chain storage of data, Fast Ledger Protocol (FLP) works to increase the speed of storing data on a blockchain. This technology makes use of a system of shards that are triggered to store a copy of the data only when an update is needed. Through this technology, transactions are not only faster but also cheaper.

Data can also be encrypted to increase privacy. The encryption can be done with a standardized one-way encryption algorithm such as a hashing algorithm, which is only decryptable with the key, or with a symmetric encryption algorithm which is decryptable with the key used for encryption<sup>8</sup>. The type of encryption used depends on the requirements of the project and the information that needs to be stored.

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<sup>8</sup> <https://www.sciencedirect.com/topics/computer-science/symmetric-encryption>.

In addition to the storage and encrypted data techniques, an additional layer of security can be implemented. With cloud-based services([Eluubek kyzy et al., 2021](#)), specialized hardware firewalls are available to protect the data event.

### **Decentralized storage and identity.**

The compliance of blockchain with the GDPR is a controversial issue in terms of personal information being able to be included in the blockchain and thus remain immutable, and this is one of the fundamental pieces of its functioning, depriving the interested party of requesting the Processor to delete the personal data, something that would also be extended to the provisions of data conservation of personal data (for the minimum essential time) and the accuracy regarding the updating of said data. The provisions on the processor and the data controller would also be difficult to comply with when it is not just one agent who controls the network. Therefore, the design of the system must also take into account this characteristic. In the case of personal data, the design of the system must comply with the European data protection regulation scheme, so that personal data can be stored in user wallets, reducing the risk of large-scale data breaches, as personal data is only shared with other parties with user permission.

- **Data communication**

It refers to how blockchain-based technologies share traceability information with end consumers. Transparency in the architecture of the systems is essential to guarantee and audit this information to the consumer. Most cases, a QR code or NFC tag can be scanned to access information about the respective product which includes images or complex and heavy data from the farm, origin, or animal appearance. This data is stored in external servers to the blockchain. In a system that guarantees and advertises the traceability of information through blockchain technology that uses databases and external elements, it must be differentiated that the information is really related to the transactions that are stored in the blockchain and what information comes from other sources that could be manipulated, especially if they reside in non-decentralized databases controlled by the system nodes. Within the European Union, the nutritional information that can be offered to the consumer must be supported by specific evidence and false claims must be avoided. Therefore, these information systems must also guarantee that they do not engage in misleading practices, such as making statements about a product if they are only true about a part of it or its manufacturing process. The following features have a direct relationship with what has just been exposed: the transparency of the data and its verification.

- **Data Transparency**

Due to market and competition related forces, it is becoming increasingly important to ensure the quality-related data is credible and verifiable. However, there are significant challenges to achieving these objectives due to existing technologies' limitations in capturing data in a homogeneous way and assuring the reliability of manually entered data ([Compagnucci et al., 2022](#)). As previously mentioned in the “data entry” section, automated capture can be a solution, blockchain-enabled technologies are also often

connected to a Global Positioning System (GPS) device or a radio frequency identification (RFID) reader, which allows registering the location of the product as it moves through the supply-chain, but not in all cases as it involves hefty investments.

Nevertheless, a system that is transparent and contains unified and verifiable data for all operators, including data contained in official control databases, could easily be carried out through audits simply by comparing the information provided to the consumer with the data supplied or collected in official databases, with the control of verification belonging to the producer or processor who can access/provide the data to the administration without market control of third-party commercial seals.

For example, if the system offers the consumer the name of the ship, the date, and the fishing area (data listed in official databases) related to a batch of hake, for example, it would be easy to verify it simply by crosschecking with the coordinates of the VMS fleet tracking system. In this way, a fishing cooperative could certify the accuracy of the information associated with their catches at the point of sale.

- **Data verification:**

It is further necessary that interested parties in the public know how to access raw blockchain data. If no one knows how to access this data, it cannot be checked against the information provided for consumers. Blockchain-based technologies can collect large amounts of data that can in principle be used for data analysis and independent audits. This can ideally help to identify patterns and highlight honest mistakes as well as intentional errors. Compliance Blockchain assists the enforcement of regulations, but there is a need for specific and global rules for the interactions performed in the platform, as mentioned previously Blockchain can improve processes of authenticity checking through information sharing and real-time access but also through cross-checking with official Data Bases, an aspect less explored and studied in scientific literature.

## 4. RESULTS

In the document, it is sought to systematize the evaluation of commercial technological solutions based on blockchain and applied to the agri-food sector which serves to certify production conditions.

4.1 The bibliographic research refers the data accuracy, in Blockchain-based product traceability systems, as a key factor in bringing (Gad et al., 2022) This information includes the types of data used (pertinence), the frequency of use, the sources of the data, the time of its acquisition, the characteristics of the data and where they are saved (on chain and off chain).

To illustrate of the above a case study is presented concerning fisheries management:  
1: data pertinence in this case the regulation or standard pursued is Sustainability-related regulatory enforcement

Base on variables and potential solutions identified, a critical evaluation of the case of the production and food control applied in Europe was performed to analyze which points could be improved by establishing a public-private partnership; this aspect was further analyzed in a practical case.

#### 4.2 Limitations

This study consists of a scoping literature review built on the major scientific database ScienceDirect covering the period 2019–2023 (may 26th). During this period, the researchers also include legal text database additional literature sources, Technology Abstracts and Google Scholar grey literature, references to illustrate a case study using official data records. Meanwhile the literature databases included in the investigation of the main management data requirements are need in blockchain systems incorporate high-quality, peer-reviewed articles, the case study presented in this paper is based on the professional experience of the author in the knowledge of official data bases and the potentiality of a hypothetical reuse of the data for private applications.

#### 4.3 Use case using Official Data Sources:

The case of Spanish fleets: Data entry, one of the most vulnerable parts in a blockchain-based technology system, can be done in various ways. While the information on the blockchain is virtually immutable, it needs to be ensured that the data input is not manipulated. In the Provenance case, only fishermen who have been previously registered in a Spanish official census can enter a new catch.

In this case we have two options: vessels with a blue box (which are tracked by VMS) and vessels which do not have a blue box; in that case these vessels must send a text message including GPS coordinates to avoid problems with internet connectivity at sea (like the Provenance system<sup>9</sup>).

All of them must register their catch offline on the (“diario de pesca”), which is transmitted automatically or manually to the Spanish authorities.

The fishermen who wanted to take part in the seal need to register the selling of their harvest in the auction (fish market) where the fisheries are sorted and weighed.

The verification is done by a machine learning algorithm which analyses the authorization for this vessel, the GPS locations of the vessel that the catch has been made in legal fishing zones.

Strategies to ensure the validity of data entry influence the integrity of the data. For example, in the case of vessels which have a quota assigned, the amount of selling must never exceed the quota, setting maximum amounts of an asset that can be registered by one vessel so that the vessel can only register the amount of quota that can legally be fished. These kinds of precautions not only make fraud and mistakes in entering data

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<sup>9</sup> <https://www.provenance.org/whitepaper>.

more difficult and ensure that the data entered is of high quality, but also helps the surveillance that must be done by the administration authorities.

Interacting with the blockchain generally works through a platform. In the case that we proposed, an off-chain platform is used to input data, manage landed catches, or track sales and distribution. The platform can be accessed both via a mobile app and a computer software and there you can discharge data from official records automatically, so the fishermen only need to enter their data once for having the seal.

The official platform could be linked with official central state systems (for catches and VMS position) and regional systems (selling data), but also must be open for data from the fishermen to complete data in certain cases (vessels with have not a blue box, for example). The blockchain system is built on a permission-based platform, that limits access to data so that businesses always remain in control of data that they have introduced. The platform can quickly locate products and is designed to automate the integration of legacy systems and network data.

It is further built as a modular architecture, where customers can choose which components, they want to use following the example of others commercial solutions like <sup>10</sup>. This platform design is where the core value for actors in the supply chain is created. Depending on its setup, actors can access information about every product within seconds.

This system is based on the following basic structures: it is necessary to have decentralized storage, smart contracts, and a perimeter cloud to build this system as most of the systems designed for those functionalities. However, some ideas are news, concerning combination of blockchain and edge computing<sup>11</sup> to improve the accuracy of the data provided about primary production of agrifood products.

- The basic information regarding certificates can be stored in smart contracts running on blockchain.
- The blockchain system could be based on Hyperledger Fabric<sup>12</sup> or a compatible blockchain.
- Connecting the real world to the blockchain needs to be properly investigated, but cross-checking with official databases could be done with RDF data sets previously released in the producer interface, so that producers never lose control of their data.
- A food traceability solution could be implemented by combining the Ethereum platform and IoT devices exchanging GS1 message standards.

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<sup>10</sup> <https://www.ibm.com/es-es/products/supply-chain-intelligence-suite/food-trust>

<sup>11</sup> se refiere al procesamiento de datos y la transmisión de datos en los dispositivos conectados en tiempo real en el lugar donde se generan los datos. La combinación de las dos permitirá procesar datos importantes de forma rápida y segura, al mismo tiempo que mejora la eficiencia y efectividad de la información.

<sup>12</sup> Hyperledger Fabric (Hyperledger, 2018) private, permissioned P2P, B2C operation, pluggable (PBFT) cited as suitable for supply chain for pharmaceuticals, trade financing, supply chain management

- Agricultural assets can be tokenized using ERC-721 tokens (Ali et al., 2023) in order to conduct a survey on blockchain technology and its security in the supply chain.
- Smart contracts designed on the Ethereum blockchain can form a mesh network to enhance food traceability, cost savings and improved efficiency within agricultural supply chain operations.

## 5. CONCLUSIONS

By synthesizing the elements used for comparing different blockchain technology systems in agrifood value chain management literature from the last four years (2019–2023), this paper contributes to the existing knowledge in four ways:

- (1) This paper provides an example of a generalizable data architecture that can be used to design, build, maintain and operate applications in various countries.
- (2) The paper identifies key challenges and proposes initial solutions for the application of blockchain technology to agrifood value chain management, considering the type of data architecture and data required.
- (3) It provides guidelines to assess if the right data is being used to maintain production conditions, and to improve the performance and quality of future solutions.
- (4) Finally, it identifies research gaps and suggests future research to further explore the use of blockchain technology in agri-food value chain management. The outcomes of this study create a valuable foundation for future studies in the blockchain technology and agri-food value chain management area.



## APPENDIX I.

Table 2: Papers 'collection:

Source	year	Nº	Classification*	Author	Subject/publisher	Research issue	Relevance.	Citations/readers
SCIENCE DIRECT	2019	1	A	(Zhao et al., 2019)	Computers in industry	Blockchain technology in agri- food value chain management:	Appears in first and 4 search. A synthesis of applications, challenges, and future research directions	304/1052
SCIENCE DIRECT	2022	2	B	(Marchesi et al., 2022b)	Blockchain: Research and Applications	A blockchain architecture for industrial applications		2/84
SCIENCE DIRECT	2022	3	A	(Zhang et al., 2022)	Technological Forecasting and Social Change	Critical success factors of blockchain technology to implement the sustainable supply chain using an	La mejora del blockchain de la gestión de datos y no viceversa. Blockchain improvements in data management.	5/79

						extended decision-making approach		
SCIENCE DIRECT	2020	4	B	(Mistry et al., 2020)	Mechanical System and Signal Processing	Blockchain for 5G-enabled IoT for industrial automation:	Appears in first and fourth search. A systematic review, solutions, and challenges	328/766
SCIENCE DIRECT	2021	5	A	(Hewa et al., 2021)	Journal of Network and Computer Applications	Study of many applications that improve the service with the “blessings” of blockchain and smart contracts.	Appears in first and second search. Survey on blockchain based smart contracts: Applications, opportunities, and challenges	1/131
SCIENCE DIRECT	2019	6	A	(Azzi et al., 2019)	Computers & Industrial Engineering	The power of a blockchain-based supply chain.	Appears in first and third search. How the blockchain can be integrated into the supply chain architecture to create a reliable, transparent, authentic, and secure system	3/269
SCIENCE DIRECT	2020	7	A	(Lezohe et al., 2020)	Computers in Industry	Agri-food 4.0: A survey of the supply chains and	Appears in first and second search.	274/1072

						technologies for the future agriculture.	new 4.0 trends in technologies and Agri-Food Supply Chain Challenges.	
SCIENCE DIRECT	2020	8	C	(Köhler & Pizzol, 2020)	Journal of Cleaner Production	Technology assessment of blockchain-based technologies in the food supply chain.	how blockchain-based technologies are implemented in food supply chains, as an element in a system of technologies.	116/412
SCIENCE DIRECT	2021	9		(Kshetri, 2021)	International Journal of Information Management	Blockchain and sustainable supply chain management in developing countries.	Blockchain in developing countries. How it can institutional deficiencies, transparency can benefit less powerful members in supply chains.	67/346
SCIENCE DIRECT	2023	10	A	(Pakseresht et al., 2023)	Sustainable Production and Consumption	The intersection of blockchain technology and circular economy in the	Scoping review regarding the role of blockchain technology in the transition towards a	1/98

						agri-food sector General Study of Block Chain Properties.	circular food system. General Study of Block Chain Properties.	
SCIENCE DIRECT	2022	11	C	(Compagnucci et al., 2022)	Journal of Cleaner Production	Uncovering the potential of blockchain in the agri-food supply chain: An interdisciplinary case study	Case study	2/116
SCIENCE DIRECT	2021	12	C	(Saurabh & Dey, 2021)	Journal of Cleaner Production	Blockchain technology adoption, architecture, and sustainable agri- food supply chains.	Case study. The paper identified a few potential drivers of blockchain technology adoption and propose an architecture model.	159/625
SCIENCE DIRECT	2021	13	A	(Dey & Shekhawat, 2021)	Journal of Cleaner Production	Blockchain for sustainable e- agriculture:	Appears in third and fourth search. Literature review, architecture for data management, and implications	28/1410

SCIENCE DIRECT	2023	14	C	(Sezer et al., 2023)	Internet of things	PPFchain: A novel framework privacy-preserving blockchain-based federated learning method for sensor networks	The paper identified a few potential drivers of blockchain technology adoption and propose an architecture model using electrochemical sensors.	12
SCIENCE DIRECT		15	A	(Machado et al., 2020)	Trends in Food Science & Technology	Blockchain technology for the management of food sciences researches	It appears in first and fourth search. Literature review	16/107
SCIENCE DIRECT		16	C	(Sezer et al., 2022)		TPPSUPPLY : A traceable and privacy-preserving blockchain system architecture for the supply chain	new framework based on permissioned blockchain architecture that balances anonymity and transparency, ensures traceability and privacy by using on-chain and off-chain smart contracts.	12

SCIENCE DIRECT		17	B	(Eluubek kzy et al., 2021)	Expert Systems with Applications	Blockchain for consortium: A practical paradigm in agricultural supply chain system	A new design is proposed for solve the problems of trustability, scalability, and share amount assignment.	25/121
SCIENCE DIRECT	2022	18	A	(Gad et al., 2022)	Journal of King Saud University - Computer and Information Sciences	Emerging Trends in Blockchain Technology and Applications: A Review and Outlook	Literature review favorite publication venues, the hottest research areas, about the status quo and emerging trends and frontiers of Blockchain	17/176
SCIENCE DIRECT	2022	19	C	(Manning et al., 2022)	Trends in Food Science & Technology	Artificial intelligence and ethics within the food sector: Developing a common language for technology adoption across the supply chain	How AI applications are increasingly being adopted in food supply chains.	6/92
SCIENCE DIRECT	2019	20	C	(Bayano-Tejero et al., 2019)	Computers and Electronics in Agriculture	Machine to machine connections for integral	Case study	5/47

						management of the olive production		
SCIENCE DIRECT	2019	21	A	(Mohanta et al., 2019)	Internet of things	Blockchain technology: A survey on applications and security privacy Challenges	bibliographic research	211/466
SCIENCE DIRECT	2020	22	A	(Sunny et al., 2020b)	Computers & Industrial Engineering	Supply chain transparency through blockchain-based traceability: An overview with demonstration	Case study based in an overview of the various blockchain-based traceability solutions reported in the literature.	158/534
SCIENCE DIRECT	2020	23	C	(Tönnissen & Teuteberg, 2020)	International Journal of Information Management	Analyzing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies	“The blockchain lead not to the removal of intermediaries in operational supply chains”	193/710

SCIENCE DIRECT	2019	24	C	(Pearson et al., 2019)	Global Food Security	Are Distributed Ledger Technologies the panacea for food traceability?	It provides an overview of the application of distributed ledger technology (DLT) within the food chain.	113/359



## APPENDIX II.

Table 3: Main regulatory control, monitoring provisions that require the registration and exploitation of data derived from agri-food production in Spain.

BOE
Regulation (EC) No 178/2002 of the European Parliament and of the Council of January 28, 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.
Directive 2001/95/EC of the European Parliament and of the Council of December 3, 2001 on general product safety.
Ley 17/2011, de 17 de Julio, on food safety and nutrition.
Real Decreto 1808/1991, de 13 de diciembre, that regulates the mentions or marks that allow to identify the batch to which a food product belongs (BOE December 25, 1991).
Real Decreto 2207/95, de 28 de diciembre, on hygiene of food products (B.O.E 27.02.1996), result of the transposition of the Directive 93/43/CEE.
Real Decreto 479/2004, de 26 de marzo which establishes and regulates the General Registry of Livestock Farms.
Real Decreto 728/2007, de 13 de junio by which it is established and regulates the General Registry of Livestock Movements and the Registry general identification of individual animals.
Real Decreto 1614/2008, de 3 de octubre, relating to the animal health requirements of animals and aquaculture products, as well as the prevention and control of certain diseases of aquatic animals.
Electronic Record of Transactions and Operations with Phytosanitary Products (RETO) established the Real Decreto 285/2021, de 20 de abril.
Real Decreto 1311/2012, de 14 de septiembre which establishes the framework for action to achieve a sustainable use of plant protection products amended by Real Decreto 1050/2022, de 27 de diciembre, modifying Royal Decree 1311/2012, of September 14, establishing the framework of action to achieve a sustainable use of phytosanitary products.
PROLAC database. Real Decreto 95/2019, de 1 de marzo, which establishes the contracting conditions in the dairy sector and regulates the recognition of producer organizations and interprofessional organizations in the sector,

ARCA system regulated in the Real Decreto 45/2019, de 8 de febrero which establishes the zootechnical standards applicable to purebred breeding animals, hybrid breeding pigs and their reproductive material, updating the National Program for the conservation, improvement and promotion of livestock breeds.
Computer system for registering animal feed establishments. Real Decreto 629/2019, de 31 de octubre.
ECOGAN system created by the Royal Decree that regulates the general registry of best available techniques in farms and the support for the calculation, monitoring, and notification of emissions in livestock.
The National Registry of Producer Organizations and Associations of Producer Organizations regulated in the Real Decreto 532/2017, de 26 de mayo.
The State Register of organizations and associations of organizations of producers of raw tobacco referred to in the Real Decreto 969/2014, de 21 de noviembre, which regulates the recognition of producer organizations, the extension of standards, contractual relations and the communication of information in the raw tobacco sector.
The National Register of organizations and associations of organizations of milk producers regulated in the Real Decreto 95/2019, de 1 de marzo.
The National Registry of organizations and associations of producer organizations provided for in el Real Decreto 541/2016, de 25 de noviembre, which regulates the recognition of producer organizations and their associations in the rabbit sector.
Wine Sector Market Information System del Real Decreto 739/2015, de 31 de julio.
Unified information system of the dairy sector regulated in the Real Decreto 319/2015, de 24 de abril, on mandatory declarations to be made by first buyers and producers of milk and dairy products from cows, sheep and goats.
REGMAQ System: Real Decreto 448/2020, de 10 de marzo, on characterization and registration of agricultural machinery.
Information system of the olive markets regulated in the Real Decreto 861/2018, de 13 de julio, establishing the basic regulations on mandatory declarations in the olive oil and table olives sectors.
El Real Decreto 1054/2021, de 30 de noviembre which establishes and regulates the Register of professional plant operators, the measures to be complied with by professional operators authorized to issue phytosanitary passports and the obligations of professional operators of reproductive plant material and modifies various royal decrees in matters of farming.
Other data sources
The data of the application for CAP aid established in the Real Decreto 1075/2014, de 19 de diciembre revoked by Real Decreto 1048/2022, de 27 de diciembre, on the application, from 2023, of interventions in the form of direct payments and the establishment of common requirements in the framework of the Strategic Plan of the Common Agricultural Policy, and the regulation of the single application of the integrated management and control system.
The data related to payments of the European agricultural funds, FEAGA and FEADER, compiled based on the provisions of the Real Decreto 92/2018, de 2 de marzo.

Sistema TRACES ( <i>TRAdE Control and Expert System</i> ) is a web-based veterinarian certification tool used by the European Union for controlling the import and export of live animals and animal products within and without its borders. Its network.
Real Decreto 1045/2022, de 27 de diciembre, on basic income support rights for the sustainability of the Common Agricultural Policy.
Real Decreto 1046/2022, de 27 de diciembre, regulating the governance of the Strategic Plan of the Common Agricultural Policy in Spain and of the European agricultural funds FEAGA and Feader.
Real Decreto 1047/2022, de 27 de diciembre, regulating the management and control system of Strategic Plan interventions and other Common Agricultural Policy aids.
Real Decreto 1049/2022, de 27 de diciembre, establishing the rules for the application of reinforced conditionalities and social conditionalities that beneficiaries of Common Agricultural Policy aids receiving direct payments, certain annual development payments and the Programme for Specific Options for Distance and Insularity (POSEI) must comply with.
Real Decreto 1051/2022, de 27 de diciembre, establishing rules for sustainable nutrition in agricultural soils.
Real Decreto 1054/2022, de 27 de diciembre, establishing and regulating the Information System for agricultural and livestock holdings and agricultural production, as well as the Autonomous Register of agricultural holdings and the Digital Farm Record.

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