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TOPICAL REVIEW

Blockchain Technology to Support Agri-Food Supply Chains: A Comprehensive Review

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ABSTRACT Blockchain technology is a distributed ledger that guarantees the immutability of data and asset tracking. Its characteristics can result in an improvement to traditional agri-food Supply Chains. Blockchain-based traceability systems let producers improve their visibility and consumers trust the products they buy and where they come from. Actual literature lacks an exhaustive analysis of the benefits and drawbacks of Blockchain applied to the agri-food domain. This paper aims to overcome this issue: to understand the state-of-the-art related to the application of Blockchain in the agri-food sector, we screened 183 papers and performed a literature review answering six Research Questions. The work takes into consideration the advantages and disadvantages of implementing such paradigm, with an analysis on the role of industries. The main findings are related to research directions: they regard the lack of training both for industries and stakeholders, the involvement of additional technologies (i.e., Big Data, Edge Computing), and the absence of supporting tools for developers.

INDEX TERMS Blockchain, supply chain, agri-food, traceability, review.

I. INTRODUCTION

Blockchain technology is part of the Distributed Ledger Technologies (DLTs) and is used to record transactions across a network of computers, called nodes. It uses cryptography to ensure that once data is entered in the chain, it cannot be manipulated. This approach ensures transparency and security: Blockchain can be used for tracking information and assets [1].

In the agri-food domain, Blockchain can modernize the way food is traced throughout the Supply Chain: by using this technology, each step of the food Supply Chain, from production to consumption, can be tracked and recorded to be trustable from the consumer point of view [2]. This allows for a more efficient food control and safety: producers can improve their visibility too.

Furthermore, Blockchain technology can also be used to create digital identities for food products, including information such as origin, production method, and certifications. This would allow consumers to make more informed decisions about the food they purchase and also allows for better tracking of sustainability and ethical production methods. Overall, Blockchain technology has the potential to significantly improve the transparency and the security of the agri-food supply chain, and to increase consumer trust in the food system.

Therefore, a comprehensive evaluation of Blockchain-based traceability systems is lacking in the literature, both in terms of technical implementation and advantages and disadvantages. To that end, we conduct a literature review to identify and assess the level of maturity in the use of Blockchain technology to improve agri-food. We propose six Research Questions that aim to explore the role of Blockchain technology in supporting agri-food Supply Chains, both from the consumers and stakeholders point of views. The analysis is based on 183 main papers, after a process of data gathering and filtering through the PRISMA workflow [3]. We analyze the industries involvement in the process of adopting a distributed architecture together with some security aspects. We also discuss about some future research directions for industries and for Blockchain developers.

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The paper is organised as follows. Section II provides an overview of Blockchain technology and emphasizes the advantages of using Blockchain systems in the agri-food SC industry, together with a common architecture to show the main components in a Blockchain-based traceability system. Section III discusses relevant work and compares this review to others that are already available. Section IV discusses the applied research methodology as well as the process of gathering relevant research papers. Section V provides answers to the Research Questions (RQs). The study concludes with some closing remarks and an examination of future directions.

II. BACKGROUND – BLOCKCHAIN TECHNOLOGY

Blockchain is a technology that is distinguished by the decentralization and spread of its database across different devices. Unlike centralized systems, Blockchain and more in general Distributed Ledger Technologies (DLTs) are not dependent on data stored in a single location (a server) and controlled and shared by a single subject. Each participant in the distributed ledger owns a copy of the ledger: any change in data is applied to each copy owned by participants. As a result, the Blockchain serves as a reliable and trustworthy third party [4].

Transactions between participants, once inserted, are permanently recorded, and these records are referred to as blocks, while each computer used for Blockchain processing is referred to as a node.

A mining operation, which adds blocks to the Blockchain, can be used to add transactions. The mining process is based on hash functions and computing problems, which serve as the foundation for chain security. To ensure a high level of security, the shared data is encrypted.

A. APPLICATION OF BLOCKCHAIN TECHNOLOGY IN AGRI-FOOD TRACEABILITY

The inner characteristics of Blockchain technology allow systems to be transparent and trustable. Traceability is easily reachable thanks to the immutability of data inserted in a Blockchain. Traceability is intended as the possibility to reproduce the history of products going from production to distribution [5]. Thanks to traceability, it is possible to distinguish between the responsibilities of every actor involved in a supply chain and to guarantee trust in the consumer from the food quality and safety point of view. Due to the length of a supply chain, it could be expensive to track products from raw materials to the end customers [6], so some sort of scalable and efficient system is needed. This kind of system should also be reliable to guarantee trust in the consumers [7]. Blockchain technology comes in hand thanks to its peculiarities: (i) it is a distributed system, so it does not rely on a single server that could be a point of failure, (ii) it is immutable, so it is simple to backtrack information and tampering is very difficult to accomplish, (iii) it can be both public or private [8], [9], so it can adapt to specific use cases sill guaranteeing transparency and counterfeiting prevention.

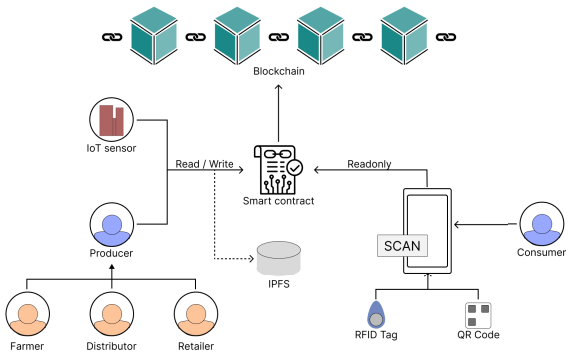

FIGURE 1. An architecture with all the components presented in different works.

A common architecture that sums up different approaches to agri-food traceability using Blockchain technology is shown in Figure 1.

Almost all proposed architectures show two main actors: the end consumer and the producer who can be extended to the farmer, the distributor, and the retailer. Each actor constitutes a node of the distributed system. The end consumer can read all the immutable traceability information from his device, through the use of a QR code or an RFID tag [10]. The producer can insert new information that is managed by some defined smart contracts; they are responsible to ensure the truthfulness of the value that is going to be added to the chain. Data can also come from IoT sensors, after a gathering process made by a central unit. All transactions are written to the Blockchain, then they can be uploaded to the InterPlanetary File System (IPFS) [11].

III. RELATED WORK

Some literature reviews on Blockchain and supply chain management have been examined. Zhao et al. conducted a review of studies published on Blockchain applied to supply chains up to 2019 [1]. The research is divided into four sections: manufacturing, sustainable water management, traceability, and information security.

The study proposed by Niknejad et al. investigates the connections between Blockchain and smart agriculture [12], focusing on traceability and IoT sensors. This research will go beyond the proposed literature reviews in search of a more general approach to agri-food using Blockchain technology. It also intends to investigate how many industries are involved in the process and whether the benefits of decentralized applications outweigh their limitations.

Paper [13] examines the growth of supply chain management using Blockchain and the IoT field, as well as the use of other Industry 5.0 technologies. The advantages of integrating such technologies space from food traceability to food composition monitoring, making customers aware of what they are purchasing; from food wasting avoidance to safety across the Supply Chain, making the entire process secure. The authors also conduct research on the major cyber security

TABLE 1. Comparison between the related work and our review.

Reference	Keywords	Blockchain based	IoT and other technologies	Industries involvement	Security aspects
[1]	Blockchain, Security, Industries, Reliability, Internet of Things, Business, Big Data	Yes	Yes	No	Privacy
[12]	Food and agriculture, R package, Bibliometrix, Scopus, VOSviewer, Blockchain	Yes	No	Yes	No relevance
[13]	Precision agriculture, Supply Chain, Blockchain, Internet of Things, Traceability, Smart contracts	Yes	Yes	No relevance	Infrastructure
[14]	Supply Chain, Traceability, Blockchain, Sustainability	Yes	No	Use cases	No relevance
[15]	Agri-food supply chain, Blockchain, Transparency, Traceability	Yes	Yes	No relevance	No relevance
[16]	Sustainable transition, Innovation technology, Production processes, Agriculture, Food, Resilience	Less importance	No	Yes	Infrastructure
[17]	Blockchain, Agricultural sector, Artificial Intelligence, Food supply chain, Digital agriculture	Yes	No	Use cases	Superficial
[18]	Blockchain, Food industry, Food supply chain, Traceability, Food data security	Yes	No	Yes	Infrastructure
[19]	/	Yes	Superficial	No	Infrastructure
[20]	Blockchain, Impact, Levels, Supply chain, Systematic review	Yes	No	Yes	Infrastructure and some Privacy considerations
[21]	Blockchain, Security, Supply chain management, Traceability, Transparency	Yes	No	Yes	Privacy
Our proposal	Blockchain, Supply Chain, Agri-food, Traceability, Review	Yes	Yes	Yes with in-depth analysis on benefits and boundaries of the new paradigm	Infrastructure and Privacy

concerns in a Blockchain-based Supply Chain network, both from the standpoint of consumer trust and IoT devices.

Paper [14] proposes a systematic literature review that takes into account the technical implementation aspects of Blockchain-based Supply Chain traceability solutions. The authors remark that just a few of the evaluated publications discuss real-life traceability solutions, particularly in terms of practicality and cost-related Supply Chain factors.

The authors of paper [15] offer a taxonomy and content analysis of all Blockchain-based frameworks, as well as an overview of the adoption models to represent platform adoption for various stakeholders. Paper [16] proposes a similar study, based largely on sustainable agri-food supply chains and with fewer Blockchain-related issues.

The benefits of applying Blockchain to agri-food traceability (i.e.: prevent counterfeiting of raw materials, use of decentralized organizations, better quality controls, and products traceability) are analyzed in papers [17] and [18], together with practical use cases and with some considerations on security aspects. Other interesting approaches regard the spreading of this technology in different countries [19], with respect to traceability, information systems, architecture, and agricultural applications, and the embryonic nature of Blockchain applications [20], that are still in a premature development phase.

Finally, authors of paper [21] study the adoption of Blockchain technology in a supply chain, proposing a SWOT analysis and identifying the main opportunities for securing Supply Chain Management (i.e. reducing anti-counterfeiting problems and costs, increasing trust, making a competitive advantage). Between the identified weaknesses, the authors focus their attention on the lack of industry standards and interoperability issues.

Our review differs from those described in this section in that it addresses not only the traceability of products throughout the SC process, but also the impact of Blockchain applied to agri-food, security issues, and the use of technologies other than Blockchain and IoT. Our plan also considers the presence of industries and their desire in adopting this new paradigm, with all of its benefits and limitations. The comparison between the different reviews is summarized in Table 1.

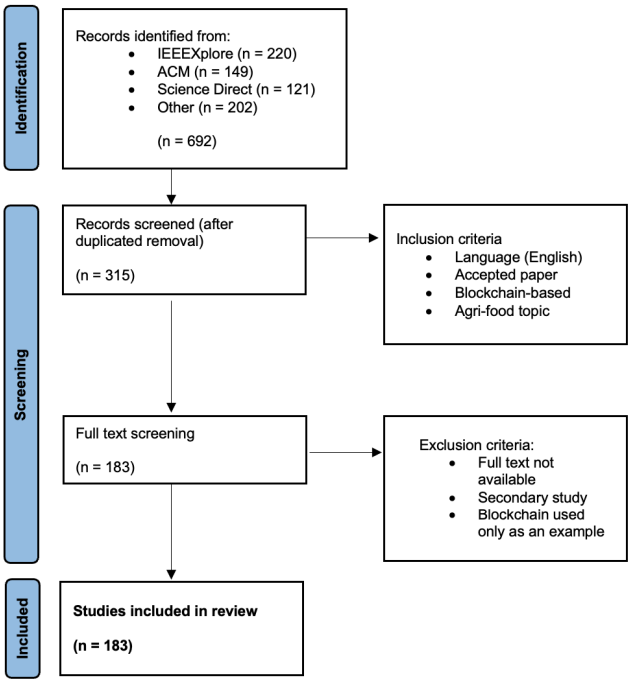

FIGURE 2. PRISMA search methodology.

IV. RESEARCH METHODOLOGY – LITERATURE REVIEW

The process for identification of relevant papers is proposed in Figure 2. It is a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram based on the guidelines described in paper [22]. The covered literature goes from 2016 to December 2022. The goal is to give new researchers identified areas in the topic of Blockchain and agri-food traceability, as well as future research directions.

A. DEFINITION OF RESEARCH QUESTIONS

The objective of this study is either a) to identify the state of the art on Blockchain technology and smart agri-food domain and b) to give appropriate foundations to highlight the gaps and trends in this field of research, as well as future research directions. To achieve this goal, we formulate the following Research Questions (RQs):

- **RQ1: What are the Blockchain research trends in the agri-food sector, starting from 2016?**
  The answer to this question seeks information about publication patterns such as the year, mode, and kind. These factors become useful in comprehending the topic's progression.
- **RQ2: What research themes have been addressed in previous studies on Blockchain technology and agriculture?**
  This RQ contains information about the key study fields on the subject and the contribution they make to the scientific community.
- **RQ3: What solutions may Blockchain build to simplify the problems of stakeholders across the full agri-food chain?** The purpose of this RQ is to learn about the benefits of using Blockchain in agri-food traceability on a wide scale, while also taking into account industry involvement.
- **RQ4: What kind of information could stakeholders receive and integrate using Blockchain?** The purpose of this RQ is to uncover product and technology information that consumers and producers can use to trace products.
- **RQ5: What are the present research gaps between the benefits of Blockchain technology and its limitations?**
  The purpose of this RQ is to identify research gaps and trends, as well as to examine existing open challenges.
- **RQ6: Is the matter of security addressed, and if so, at what level?**
  This information is useful for determining the level of security, both on the implementation and infrastructure sides.

B. PAPER SELECTION STRATEGY

Relevant databases were examined to ensure that the information inserted in the review is complete and comprehensive. A PICO (Population, Intervention, Comparison, Outcomes) approach is used to search for keywords, that can be grouped into 2 categories:

- Population-related search term: ''agri-food''.
- Intervention-related search terms: ''Blockchain'' and ''traceability''.

The submitted string is a combination of keywords connected in binary logic.

''blockchain AND traceability AND (agri OR food OR agrifood)''.

The retrieved string returns 692 results from various databases such as IEEEXplore, ACM, Science Direct, and others.

C. INCLUSION AND EXCLUSION CRITERIA

Once the studies that include the search string's keywords within the metadata (title, abstract, keywords) are identified, the impurities are removed (i.e., studies that deal with the proposed topic in a simple way even if they contain the defined keywords). To improve the reliability of the studies under consideration, inclusion and exclusion criteria are used.

Inclusion criteria:

- Publication date until 2022.
- English-written study.
- Study accepted for publication in a conference or journal.
- Study based on traceability in the agri-food Supply Chain.
- Study focused on Blockchain methods and solutions.

Exclusion criteria:

- The complete text of the study is not available.
- Study considered as secondary or tertiary (i.e., surveys).

TABLE 2. Research questions and their carried value.

Data	Value	RQ
Publication's year	From 2016 to 2022	RQ1
Search type	How is the topic analyzed?	RQ1
Search area	What kind of analysis is performed?	RQ2
Software or Knowledge-based	Is the study focused on software or on knowledge?	RQ2
Solution to problem target	How is the targeted problem solved?	RQ3
Involve industries	Are industries involved?	RQ3
Product Information	What aspect of the product does the publication cover?	RQ4
Other technologies	What technologies are used other than Blockchain?	RQ4
Gap between benefits and boundaries	Are benefits greater than limitations?	RQ5
Security topic	Is the security aspect analyzed?	RQ6

- Study where Blockchain is not the main topic, but it is used as an example.

A pool of 183 studies is included in the analysis after the application of the screening procedure.[1] The extraction and classification of data answers the provided Research Questions. The data extraction form is shown in Table 2.

V. RESULTS AND DISCUSSION

In this section, we show the main results obtained after the analysis of the selected papers. Results are categorized based on the RQs identified in Section IV.

A. RQ1: WHAT ARE THE BLOCKCHAIN RESEARCH TRENDS IN THE AGRI-FOOD SECTOR, STARTING FROM 2016?

The analysis of Figure 3 shows an increasing number of papers during the years. Studies on the topic of Blockchain applied to agri-food increased over time and are expected to constantly grow. There is a little decrease between 2020 and 2021, which can be imputed to the pandemic situation that changed research perspectives. Practical approaches start to spread in 2022: it is important to find new ways to accomplish the increasing food demand due to the world population increase [23].

Figure 4 distinguishes between different search types: 43.8% of the analyzed papers are proposals, innovative solutions with systems that are not fully validated or implemented. Implementations cover 8.2% of the analyzed paper: producers still do not have trust in implementing such systems, mainly because the Blockchain is not mature yet. 14.1% of evaluative opinions, 17.8% of validation research, and 10.8% of experiments led us to think that practical evaluations are still in progress. It is necessary to carry out some checks to confirm the added value that Blockchain can carry to Supply Chains. Almost 4.9% of the found searches focus on ethical and philosophical topics. Blockchain is not only an innovative and cutting-edge technology: it brings a new way of thinking that can have an important impact and change some aspects of our daily life.

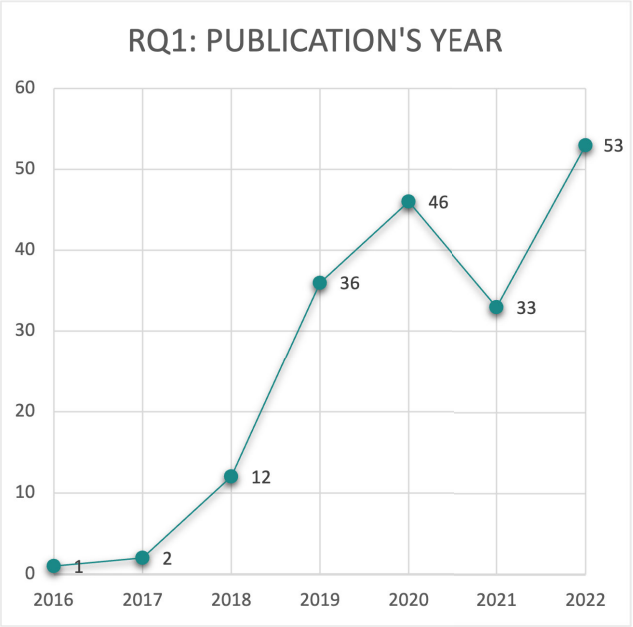

FIGURE 3. RQ1: Distribution by publishing year of selected papers.

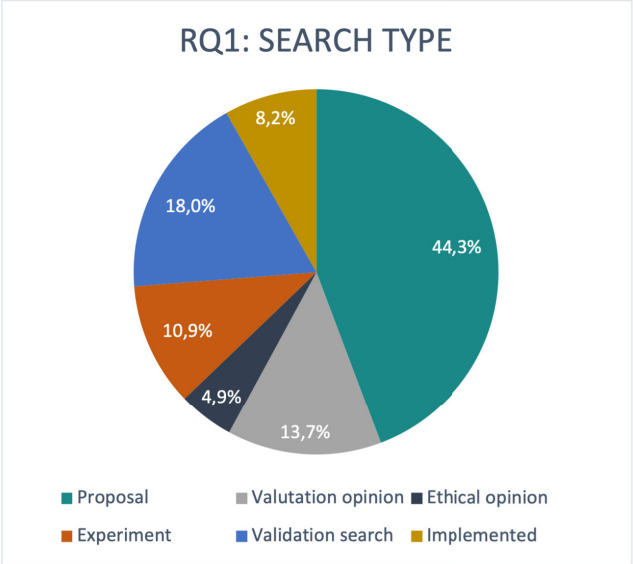

FIGURE 4. RQ1: Distribution by search type.

B. RQ2: WHAT RESEARCH THEMES HAVE BEEN ADDRESSED IN PREVIOUS STUDIES ON BLOCKCHAIN TECHNOLOGY AND AGRICULTURE?

Figure 5 shows different search areas: 75 papers refer to technology, 38 paper focus on architecture, and 23 on performance. Blockchain is not a mature technology, so researchers

[1] A replication package is available at https://politecnicobari-my.sharepoint.com/:f:/g/personal/marco_fiore_poliba_it/Eimw3a8vD5lHsBgD39p-xEABYpmVV–Pe7WgpeQeN9evMQ?e=pe2ZyM

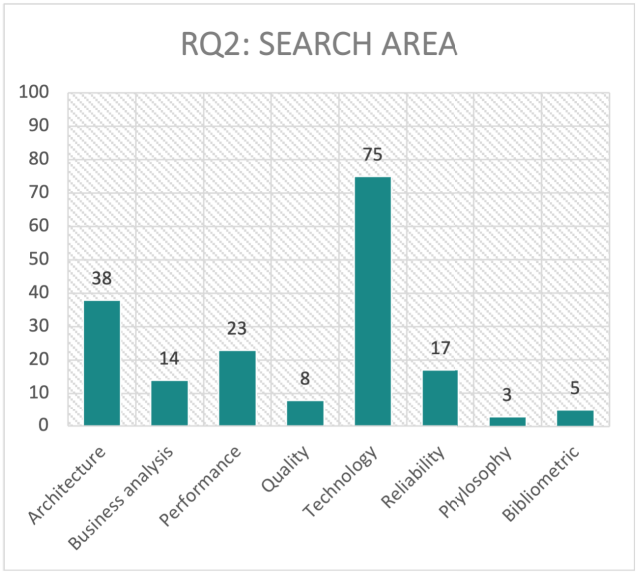

FIGURE 5. RQ2: Distribution by search area.

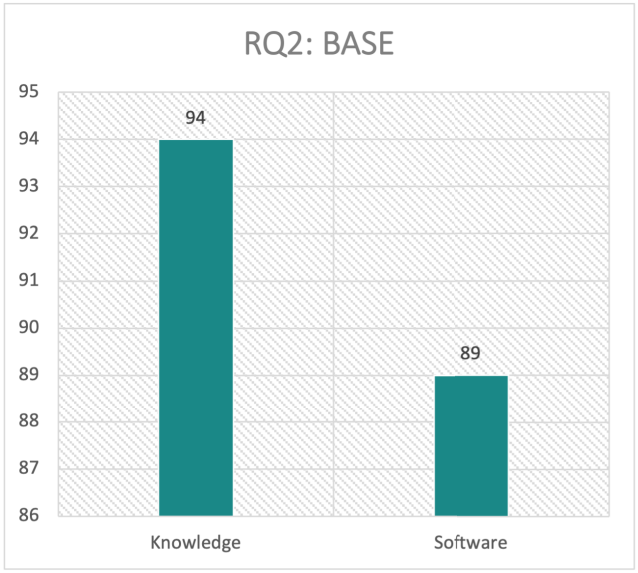

FIGURE 6. RQ2: Distribution by selected papers base, either knowledge or software.

are still finding new approaches to this topic to improve performance. 17 papers focus on reliability, 14 on business analysis, 8 on quality, 5 on bibliometrics, and 3 on philosophy: researchers highlight the importance of transparency and data immutability as driving vectors for the application of Blockchain.

Figure 6 shows the division between software-based and knowledge-based publications. The two categories are nearly similar in size, with 89 in software and 94 in knowledge: the understanding of the architectural network and the algorithms that comprise the Blockchain is developed concurrently with the software development and the technological advancement that it entails.

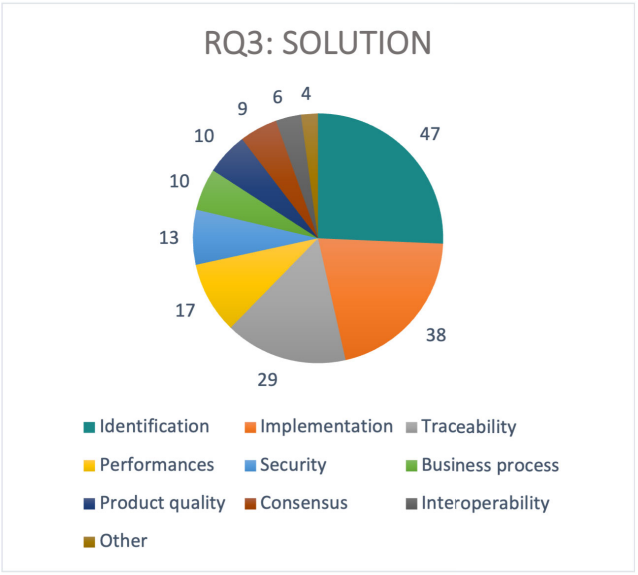

FIGURE 7. RQ3: Distribution by the proposed paper solution.

Different companies and real-world scenarios are leveraging the promise of Blockchain traceability solutions. As stated in paper [14], delivering true commercial value is difficult due to a variety of variables, including:

- Blockchain's infancy: Blockchain is a new technology, but its adoption is not widely accepted because investments in this new paradigm could result in a financial loss.
- Diffusion: Some Supply Chain sectors lack advanced traceability technologies and processes, making implementation difficult.
- Scalability: The implementation of bigger distributed systems may cause challenges with size and complexity.
- Technology barriers: There is a significant gap between platform research and real-world testing.

For these reasons, the viability and practicality of Blockchain-based traceability solutions should be validated across all Supply Chain players.

C. RQ3: WHAT SOLUTIONS MAY BLOCKCHAIN BUILD TO SIMPLIFY THE PROBLEMS OF STAKEHOLDERS ACROSS THE FULL AGRI-FOOD CHAIN?

The combination of the identification of the product at different stages of the Supply Chain, the implementation of the system, and the traceability aspects cover 62.3% of the proposed papers, as shown in Figure 7. Blockchain can identify products, track them from production to exhibition to the shelf and manage the Supply Chain to guarantee trust and transparency. A less-treated topic is interoperability (6% of analyzed papers). It could be difficult to integrate Blockchain into a system without changing the whole process. This is because Blockchain requires a distributed architecture, while lots of actual implementations are classical client-server architectures. For industries, this means reinvesting

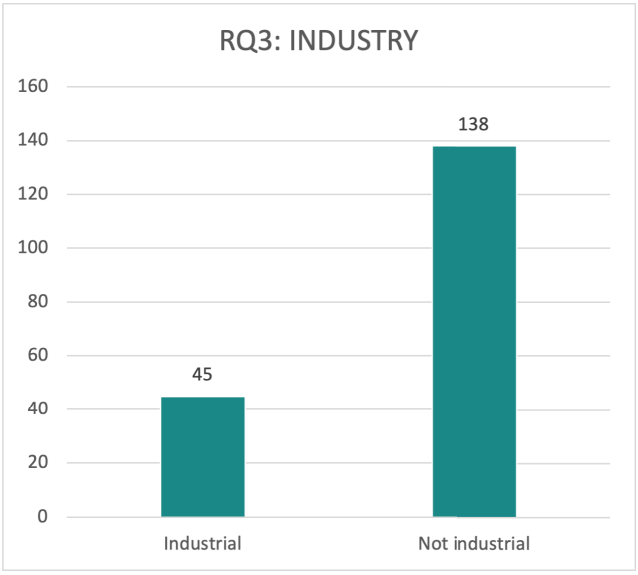

FIGURE 8. RQ3: Industries involvement.

FIGURE 9. RQ4: Traceability information proposed in papers.

money and training workers, which could lead to higher costs to switch to Blockchain.

In 138 of the selected references, as underlined in Figure 8, industries are not involved in the study. This data is the reason for the Blockchain's slow adoption as an agri-food traceability tool. The development of such technologies should begin with industries, who should be the first stakeholders to ensure the quality of the products they sell. This indicates a lack of proactivity on the part of industries to seek technological innovation. However, it should be noted that the exploitation of research figures occurs in 2018, just two years before the 2020 pandemic shifted scientific communities' interests. We also found some causes of this non-diffusion in the lack of supporting tools for developers to help them understand Blockchain and choose the best one that fits their needs.

D. RQ4: WHAT KIND OF INFORMATION COULD STAKEHOLDERS RECEIVE AND INTEGRATE USING BLOCKCHAIN?

The agri-food sector can be optimized either to track the origin of a product or to show its quality. Figure 9 shows what information was mainly considered in the articles published in this area up to December 2022. The acquired information is mainly based on the origin of the product, that is transport, storage, place of production, and processing; this information optimizes the logistical aspect of the products. Papers regarding the quality topic focus on certifications such as the Hazard Analysis and Critical Control Points (HACCP) to reduce the risk of counterfeiting and manumission, thus ensuring products and production line safety.

After the analysis of Figure 10, when compared to the treatment in the field of Edge Computing, we can see a minor increase in the treatment and use of Internet of Things (IoT) devices mixed with the field of Big Data. The majority of

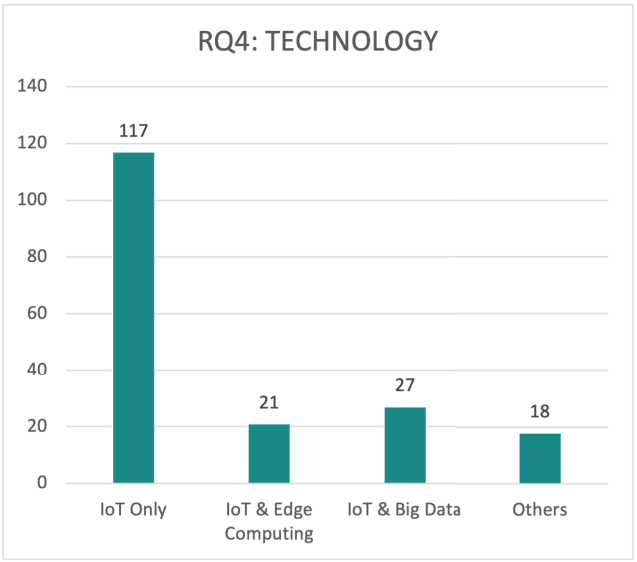

FIGURE 10. RQ4: Technologies used in selected papers.

the articles demonstrate the usage of IoT technologies in conjunction with Blockchain: IoT sensors are primarily used for tracking (i.e., for obtaining humidity and field temperatures and product transports). Factors such as data mining and the usage of edge computing techniques ensure a more optimized and secure contact point with the consumer.

E. RQ5: WHAT ARE THE PRESENT RESEARCH GAPS BETWEEN THE BENEFITS OF BLOCKCHAIN TECHNOLOGY AND ITS LIMITATIONS?

The articles examined illustrate an attempt to address Blockchain's current limitations, mostly in terms of security and consensus procedures. They emphasize the platform's

unique features and how it could ease other stages of the agri-food chain.

The benefits of Blockchain to the supply chain are numerous and have been analyzed by answering the previous research questions: a) the ability to trace products right from the cultivation phase, b) the ability to quickly identify any defective batches without having to eliminate more than necessary [24], and c) the ability to speed up the process of information collection, organization, and storage. The goal is to build customer trust and streamline producer labor by generating a digital identity for each developed product [25].

Other known benefits are:

- Enhancement of the current supply chain
- Intelligent agriculture and applied studies
- Forecasting and analysis of data models
- Framework to optimize perishable food issues, whose bias is conditioned by environment
- Integration of the system with current technologies
- Crop monitoring based on decision support systems
- Normatives that could impact the behavior of stakeholders operating the technology

A restriction emphasized by the authors of paper [26] is stakeholders' approach to new technology: the proclivity to learn a new way of managing products is subjective, and it may not be so easy to fundamentally modify how information is collected and kept. This restriction is also evident in RQ3, where about 74.5% of the publications do not have actual industry consequences. Similar impediments, as outlined in paper [27], would widen the gap between established businesses and start-ups, with the latter better prepared for the Industry 4.0 transformation.

Other known limitations regard a) the lack of simple Blockchain tools that are easy to understand; b) the lack of support and financial constraints; c) the implementation of IoT smart sensors to improve traceability; d) the definition of regulamentation and policies; e) an initial investment that is required to implement such technologies.

This analysis could lead to a shift in research focus from generating trust in consumers to establishing trust in business owners who desire more guarantees while changing their work chain. Some concepts were offered in the paper [28]. Creating tools specifically for the agri-food chain could be the first step toward a larger-scale application of Blockchain technology in the agri-food sector.

F. RQ6: IS THE MATTER OF SECURITY ADDRESSED, AND IF SO, AT WHAT LEVEL?

As shown in Figure 11, there is a growing interest in the security subject, both in terms of traceability and personal data processing, thanks to Blockchain technology. 94 publications out of a total of 185 identified both sides. 54 publications are more focused on infrastructure, whereas 28 are more concerned with traceability security. Finally, just 9 studies do not address the security issue. Because of the distributed type system, Blockchain ensures higher fraud prevention as well as network security. Furthermore, traceability can be facilitated by current technological innovation that ensures high security, as well as by the growing number of IoT devices involved in the Supply Chain.

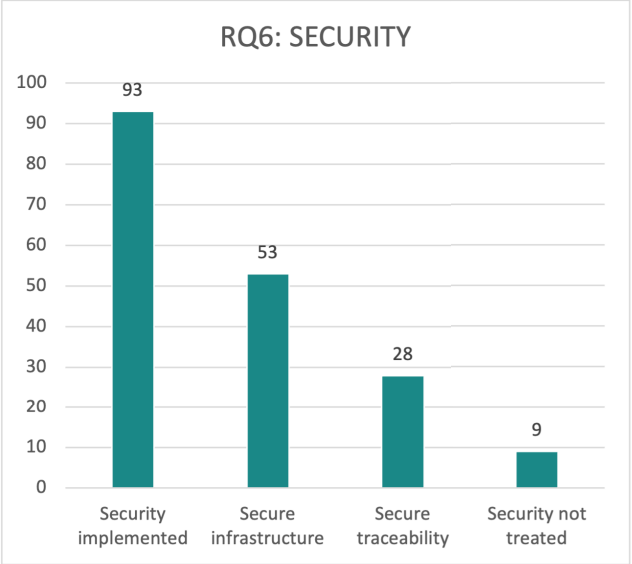

FIGURE 11. RQ6: Distribution by treatment of security topic.

VI. CONCLUSION AND FUTURE DIRECTIONS

This paper presents a review of the literature on agri-food traceability via Blockchain. Out of a total first search of 692 references, 183 studies are examined. These studies constitute a significant number for the work at hand; they can verify that the completed analysis has strong scientific validity, together with the selection of inclusion and exclusion criteria.

This provides researchers with a clear overview of the state of the art of Blockchain technology applied to agri-food Supply Chains. In 2018, interest in this topic began to develop; research interests are shifting from proposals to validations and implementations. Innovative applications of Blockchain technology have been developed for a tool whose primary purpose is to transform people's perceptions of trust. Half of the studies performed a technological examination, and 60% of them contributed to the application of Blockchain to traceability in the agri-food sector.

The industrial sector is a crucial participant in the spread of Blockchain as a traceability tool: employers are not sufficiently involved in the Blockchain deployment process. Furthermore, the pandemic situation may have contributed to the lengthening of the time required to advertise the new approach. In any case, the benefits of applying Blockchain to agri-food traceability are numerous: companies can improve their brand identity (and their sales) by ensuring products that are of high-quality; distributors can ensure efficient and transparent goods management; consumers can purchase products feeling more protected and trusting the retailer, also

by learning about the Supply Chain process that brought the product to their home by scanning a QR code on the label of that product.

With the use of the IoT, and therefore the development of Blockchain in this topic, it could be possible to reach the prefixed goal, that is to track down a product and read its chemical characteristics on the consumer smartphone. In this way, it becomes easier to track information about a product quality and origin.

Future directions regard a) the lack of training both for industries and stakeholders: researchers should find new ways to train stakeholders and to ensure that the Blockchain's main characteristics are understandable; b) the involvement of additional technologies (i.e., Big Data, Edge Computing) to create scalable and reliable platforms, regardless of the bandwidth and throughput limitations of actual Blockchain-based implementations; c) the absence of supporting tool for developers, to help them differentiate between the available Blockchain platforms and choose the best one to fit their needs.

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REFERENCES

[1] G. Zhao, S. Liu, C. Lopez, H. Lu, S. Elgueta, H. Chen, and B. M. Boshkoska, "Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions," *Comput. Ind.*, vol. 109, pp. 83–99, Aug. 2019.

[2] M. Garaus and H. Treiblmaier, "The influence of blockchain-based food traceability on retailer choice: The mediating role of trust," *Food Control*, vol. 129, Nov. 2021, Art. no. 108082.

[3] K. Petersen, R. Feldt, S. Mujtaba, and M. Mattsson, "Systematic mapping studies in software engineering," in *Proc. Electron. Workshops Comput.*, Jun. 2008, pp. 1–10.

[4] N. Patelli and M. Mandrioli, "Blockchain technology and traceability in the agrifood industry," *J. Food Sci.*, vol. 85, no. 11, pp. 3670–3678, Nov. 2020.

[5] M. M. Aung and Y. S. Chang, "Traceability in a food supply chain: Safety and quality perspectives," *Food Control*, vol. 39, pp. 172–184, May 2014.

[6] T. Bosona and G. Gebresenbet, "Food traceability as an integral part of logistics management in food and agricultural supply chain," *Food Control*, vol. 33, no. 1, pp. 32–48, Sep. 2013.

[7] B. M. Yakubu, R. Latif, A. Yakubu, M. I. Khan, and A. I. Magashi, "RiceChain: Secure and traceable Rice supply chain framework using blockchain technology," *PeerJ Comput. Sci.*, vol. 8, p. e801, Jan. 2022.

[8] G. Varavallo, G. Caragnano, F. Bertone, L. Vernetti-Prot, and O. Terzo, "Traceability platform based on green blockchain: An application case study in dairy supply chain," *Sustainability*, vol. 14, no. 6, p. 3321, Mar. 2022.

[9] A. Tan, D. Gligor, and A. Ngah, "Applying blockchain for halal food traceability," *Int. J. Logistics Res. Appl.*, vol. 25, no. 6, pp. 947–964, Jun. 2022.

[10] K. Kampan, T. W. Tsusaka, and A. K. Anal, "Adoption of blockchain technology for enhanced traceability of livestock-based products," *Sustainability*, vol. 14, no. 20, p. 13148, Oct. 2022.

[11] A. Shahid, A. Almogren, N. Javaid, F. A. Al-Zahrani, M. Zuair, and M. Alam, "Blockchain-based agri-food supply chain: A complete solution," *IEEE Access*, vol. 8, pp. 69230–69243, 2020.

[12] N. Niknejad, W. Ismail, M. Bahari, R. Hendradi, and A. Z. Salleh, "Mapping the research trends on blockchain technology in food and agriculture industry: A bibliometric analysis," *Environ. Technol. Innov.*, vol. 21, Feb. 2021, Art. no. 101272.

[13] S. A. Bhat, N.-F. Huang, I. B. Sofi, and M. Sultan, "Agriculture-food supply chain management based on blockchain and IoT: A narrative on enterprise blockchain interoperability," *Agriculture*, vol. 12, no. 1, p. 40, Dec. 2021.

[14] T. K. Dasaklis, T. G. Voutsinas, G. T. Tsoulfas, and F. Casino, "A systematic literature review of blockchain-enabled supply chain traceability implementations," *Sustainability*, vol. 14, no. 4, p. 2439, Feb. 2022.

[15] D. T. Bhatia, "Digitalization of agri-food supply chain with blockchain technology: A review, taxonomy and open research issues," Tech. Rep.

[16] G. P. Agnusdei and B. Coluccia, "Sustainable agrifood supply chains: Bibliometric, network and content analyses," *Sci. Total Environ.*, vol. 824, Jun. 2022, Art. no. 153704.

[17] M. Alobid, S. Abujudeh, and I. Szűcs, "The role of blockchain in revolutionizing the agricultural sector," *Sustainability*, vol. 14, no. 7, p. 4313, Apr. 2022.

[18] S. Tanwar, A. Parmar, A. Kumari, N. K. Jadav, W.-C. Hong, and R. Sharma, "Blockchain adoption to secure the food industry: Opportunities and challenges," *Sustainability*, vol. 14, no. 12, p. 7036, Jun. 2022.

[19] U. Marfuah and I. Yuliasih, "Blockchain traceability for agroindustry—A literature review and future agenda," *IOP Conf. Ser., Earth Environ. Sci.*, vol. 1063, no. 1, Jul. 2022, Art. no. 012056.

[20] J. Sultana, S. Y. Teoh, and S. Karanasios, "The impact of blockchain on supply chains: A systematic review," *Australas. J. Inf. Syst.*, vol. 26, pp. 1–38, Sep. 2022.

[21] U. Agarwal, V. Rishiwal, S. Tanwar, R. Chaudhary, G. Sharma, P. N. Bokoro, and R. Sharma, "Blockchain technology for secure supply chain management: A comprehensive review," *IEEE Access*, vol. 10, pp. 85493–85517, 2022.

[22] B. Kitchenham and S. Charters, "Guidelines for performing systematic literature reviews in software engineering," Tech. Rep., 2007.

[23] R. B. Ayed, M. Hanana, S. Ercisli, R. Karunakaran, A. Rebai, and F. Moreau, "Integration of innovative technologies in the agri-food sector: The fundamentals and practical case of DNA-based traceability of olives from fruit to oil," *Plants*, vol. 11, no. 9, p. 1230, May 2022.

[24] Y. Kayikci, N. Subramanian, M. Dora, and M. S. Bhatia, "Food supply chain in the era of industry 4.0: Blockchain technology implementation opportunities and impediments from the perspective of people, process, performance, and technology," *Prod. Planning Control*, vol. 33, nos. 2–3, pp. 301–321, 2020.

[25] L. Cocco, R. Tonelli, and M. Marchesi, "Blockchain and self sovereign identity to support quality in the food supply chain," *Future Internet*, vol. 13, no. 12, p. 301, Nov. 2021.

[26] M. P. Kramer, L. Bitsch, and J. H. Hanf, "The impact of instrumental stakeholder management on blockchain technology adoption behavior in agri-food supply chains," *J. Risk Financial Manage.*, vol. 14, no. 12, p. 598, Dec. 2021.

[27] H. Treiblmaier, A. Rejeb, R. van Hoek, and M. Lacity, "Intra- and interorganizational barriers to blockchain adoption: A general assessment and coping strategies in the agrifood industry," *Logistics*, vol. 5, no. 4, p. 87, Dec. 2021.

[28] J. P. Domínguez and P. Roseiro, "Blockchain: A brief review of agri-food supply chain solutions and opportunities," *ADCAIJ, Adv. Distrib. Comput. Artif. Intell. J.*, vol. 9, no. 4, pp. 95–106, Dec. 2020.

[29] G. Zhao, S. Liu, and C. Lopez, "A literature review on risk sources and resilience factors in agri-food supply chains," in *Proc. Working Conf. Virtual Enterprises*. Cham, Switzerland: Springer, 2017, pp. 739–752.

[30] J. F. Galvez, J. C. Mejuto, and J. Simal-Gandara, "Future challenges on the use of blockchain for food traceability analysis," *TrAC Trends Anal. Chem.*, vol. 107, pp. 222–232, Oct. 2018.

[31] M. U. Hassan, M. H. Rehmani, and J. Chen, "Privacy preservation in blockchain based IoT systems: Integration issues, prospects, challenges, and future research directions," *Future Gener. Comput. Syst.*, vol. 97, pp. 512–529, Aug. 2019.

[32] H. Feng, X. Wang, Y. Duan, J. Zhang, and X. Zhang, "Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges," *J. Cleaner Prod.*, vol. 260, Jul. 2020, Art. no. 121031.

[33] D. Mao, Z. Hao, F. Wang, and H. Li, "Novel automatic food trading system using consortium blockchain," *Arabian J. Sci. Eng.*, vol. 44, no. 4, pp. 3439–3455, Apr. 2019.

[34] D. Mao, Z. Hao, F. Wang, and H. Li, "Innovative blockchain-based approach for sustainable and credible environment in food trade: A case study in Shandong Province, China," *Sustainability*, vol. 10, no. 9, p. 3149, Sep. 2018.

[35] L. Marchesi, K. Mannaro, and R. Porcu, "Automatic generation of blockchain agri-food traceability systems," in *Proc. IEEE/ACM 4th Int. Workshop Emerg. Trends Softw. Eng. Blockchain (WETSEB)*, May 2021, pp. 41–48.

[36] C. Martinez-Rendon, D. Camarmas-Alonso, J. Carretero, and J. L. Gonzalez-Compean, "On the continuous contract verification using blockchain and real-time data," *Cluster Comput.*, vol. 25, pp. 2179–2201, Feb. 2021.

[37] M. Giacalone, V. Santarcangelo, V. Donvito, O. Schiavone, and E. Massa, "Big data for corporate social responsibility: Blockchain use in Gioia del Colle DOP," *Qual. Quantity*, vol. 55, no. 6, pp. 1945–1971, Dec. 2021.

[38] M. Vlachopoulou, C. Ziakis, K. Vergidis, and M. Madas, "Analyzing AgriFood-tech e-business models," *Sustainability*, vol. 13, no. 10, p. 5516, May 2021.

[39] F. Casino, V. Kanakaris, T. K. Dasaklis, S. Moschuris, S. Stachtiaris, M. Pagoni, and N. P. Rachaniotis, "Blockchain-based food supply chain traceability: A case study in the dairy sector," *Int. J. Prod. Res.*, vol. 59, no. 19, pp. 5758–5770, Oct. 2021.

[40] X. Lin, S.-C. Chang, T.-H. Chou, S.-C. Chen, and A. Ruangkanjanases, "Consumers' intention to adopt blockchain food traceability technology towards organic food products," *Int. J. Environ. Res. Public Health*, vol. 18, no. 3, p. 912, Jan. 2021.

[41] R. Mavilia and R. Pisani, "Blockchain for agricultural sector: The case of South Africa," *Afr. J. Sci., Technol., Innov. Develop.*, vol. 14, no. 3, pp. 845–851, 2021.

[42] M. Sangeetha, G. Thejaswini, A. Shoba, S. Santoshi Gaikwad, R. T. Amretasre, and S. Nivedita, "Design and development of a crop quality monitoring and classification system using IoT and blockchain," *J. Phys., Conf. Ser.*, vol. 1964, no. 6, Jul. 2021, Art. no. 062011.

[43] A. Scuderi, V. Foti, and G. Timpanaro, "The supply chain value of POD and PGI food products through the application of blockchain," *Calitatea*, vol. 20, no. S2, pp. 580–587, 2019.

[44] F. J. Haro-Olmo, J. A. Alvarez-Bermejo, A. J. Varela-Vaca, and J. A. López-Ramos, "Blockchain-based federation of wireless sensor nodes," *J. Supercomput.*, vol. 77, no. 7, pp. 7879–7891, Jul. 2021.

[45] A. Ismailisufi, T. Popovic, N. Gligoric, S. Radonjic, and S. Šandi, "A private blockchain implementation using multichain open source platform," in *Proc. 24th Int. Conf. Inf. Technol. (IT)*, Feb. 2020, pp. 1–4.

[46] D. Syromyatnikov, A. Geiko, S. Kuashbay, and A. Sadikbekova, "Agile supply chain management in agricultural business," *Int. J. Supply Chain Manag.*, vol. 9, no. 3, p. 377, 2020.

[47] J. D. Borrero, "Agri-food supply chain traceability for fruit and vegetable cooperatives using blockchain technology," *Revista de Economía Pública, Social y Cooperativa*, vol. 95, pp. 71–94, Jan. 2019.

[48] M. P. Kramer, L. Bitsch, and J. Hanf, "Blockchain and its impacts on agri-food supply chain network management," *Sustainability*, vol. 13, no. 4, p. 2168, Feb. 2021.

[49] N. Amarfii-Railean, "Streamlining management in the agri-food sector through blockchain technology," *Eastern Eur. J. Regional Stud. (EEJRS)*, vol. 6, no. 2, pp. 92–107, 2020.

[50] U. Sengupta and H. M. Kim, "Meeting changing customer requirements in food and agriculture through the application of blockchain technology," *Frontiers Blockchain*, vol. 4, p. 5, Feb. 2021.

[51] H. Fu, C. Zhao, C. Cheng, and H. Ma, "Blockchain-based agri-food supply chain management: Case study in China," *Int. Food Agribusiness Manage. Rev.*, vol. 23, no. 5, pp. 667–679, Dec. 2020.

[52] H. Patel and B. Shrimali, "AgriOnBlock: Secured data harvesting for agriculture sector using blockchain technology," *ICT Exp.*, vol. 9, no. 2, pp. 150–159, Apr. 2023.

[53] F. Casino, V. Kanakaris, T. K. Dasaklis, S. Moschuris, and N. P. Rachaniotis, "Modeling food supply chain traceability based on blockchain technology," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 2728–2733, 2019.

[54] R. B. dos Santos, N. M. Torrisi, and R. P. Pantoni, "Third party certification of agri-food supply chain using smart contracts and blockchain tokens," *Sensors*, vol. 21, no. 16, p. 5307, Aug. 2021.

[55] A. Kumar, "Improvement of public distribution system efficiency applying blockchain technology during pandemic outbreak (COVID-19)," *J. Humanitarian Logistics Supply Chain Manage.*, vol. 11, no. 1, pp. 1–28, Nov. 2020.

[56] L. Manning, *Food and Drink-Good Manufacturing Practice: A Guide to Its Responsible Management (GMP7)*. Hoboken, NJ, USA: Wiley, 2018.

[57] A. B. Abdulhussein, A. K. Hadi, and M. Ilyas, "Design a tracing system for a seed supply chain based on blockchain," in *Proc. 3rd Int. Conf. Eng. Technol. Appl. (IICETA)*, Sep. 2020, pp. 209–214.

[58] R. S. Alonso, I. Sittón-Candanedo, Ó. García, J. Prieto, and S. Rodríguez-González, "An intelligent edge-IoT platform for monitoring livestock and crops in a dairy farming scenario," *Ad Hoc Netw.*, vol. 98, Mar. 2020, Art. no. 102047.

[59] A. C. An, P. T. X. Diem, L. T. T. Lan, T. Van Toi, and L. D. Q. Binh, "Building a product origins tracking system based on blockchain and PoA consensus protocol," in *Proc. Int. Conf. Adv. Comput. Appl. (ACOMP)*, Nov. 2019, pp. 27–33.

[60] A. Arena, A. Bianchini, P. Perazzo, C. Vallati, and G. Dini, "BRUSCHETTA: An IoT blockchain-based framework for certifying extra virgin olive oil supply chain," in *Proc. IEEE Int. Conf. Smart Comput. (SMARTCOMP)*, Jun. 2019, pp. 173–179.

[61] J. Astill, R. A. Dara, M. Campbell, J. M. Farber, E. D. G. Fraser, S. Sharif, and R. Y. Yada, "Transparency in food supply chains: A review of enabling technology solutions," *Trends Food Sci. Technol.*, vol. 91, pp. 240–247, Sep. 2019.

[62] G. Baralla, A. Pinna, and G. Corrias, "Ensure traceability in European food supply chain by using a blockchain system," in *Proc. IEEE/ACM 2nd Int. Workshop Emerg. Trends Softw. Eng. Blockchain (WETSEB)*, May 2019, pp. 40–47.

[63] D. Bumblauskas, A. Mann, B. Dugan, and J. Rittmer, "A blockchain use case in food distribution: Do you know where your food has been? *Int. J. Inf. Manage.*, 52, Jun. 2020, Art. no. 102008.

[64] C. Yu, Y. Zhan, and Z. Li, "Using blockchain and smart contract for traceability in agricultural products supply chain," in *Proc. Int. Conf. Internet Things Intell. Appl. (ITIA)*, Nov. 2020, pp. 1–5.

[65] M. P. Caro, M. S. Ali, M. Vecchio, and R. Giaffreda, "Blockchain-based traceability in agri-food supply chain management: A practical implementation," in *Proc. IoT Vertical Topical Summit Agricult. Tuscany (IoT Tuscany)*, May 2018, pp. 1–4.

[66] H. Chen, Z. Chen, F. Lin, and P. Zhuang, "Effective management for blockchain-based agri-food supply chains using deep reinforcement learning," *IEEE Access*, vol. 9, pp. 36008–36018, 2021.

[67] Y. Chen, Y. Li, and C. Li, "Electronic agriculture, blockchain and digital agricultural democratization: Origin, theory and application," *J. Cleaner Prod.*, vol. 268, Sep. 2020, Art. no. 122071.

[68] P. Chun-Ting, L. Meng-Ju, H. Nen-Fu, L. Jhong-Ting, and S. Jia-Jung, "Agriculture blockchain service platform for farm-to-fork traceability with IoT sensors," in *Proc. Int. Conf. Inf. Netw. (ICOIN)*, Jan. 2020, pp. 158–163.

[69] M. Creydt and M. Fischer, "Blockchain and more–Algorithm driven food traceability," *Food Control*, vol. 105, pp. 45–51, Nov. 2019.

[70] X. Dong, X. Zheng, X. Lu, and X. Lin, "A traceability method based on blockchain and Internet of Things," in *Proc. IEEE Int. Conf Parallel Distrib. Process. With Appl., Big Data Cloud Comput., Sustain. Comput. Commun., Social Comput. Netw. (ISPA/BDCloud/SocialCom/SustainCom)*, Dec. 2019, pp. 1511–1518.

[71] F. Tian, "An agri-food supply chain traceability system for China based on RFID & blockchain technology," in *Proc. 13th Int. Conf. Service Syst. Service Manage. (ICSSSM)*, Jun. 2016, pp. 1–6.

[72] F. Tian, "A supply chain traceability system for food safety based on HACCP, blockchain & Internet of Things," in *Proc. Int. Conf. Service Syst. Service Manage.*, Jun. 2017, pp. 1–6.

[73] T. Ferdousi, D. Gruenbacher, and C. M. Scoglio, "A permissioned distributed ledger for the U.S. beef cattle supply chain," *IEEE Access*, vol. 8, pp. 154833–154847, 2020.

[74] K. Gai, Z. Fang, R. Wang, L. Zhu, P. Jiang, and K. R. Choo, "Edge computing and lightning network empowered secure food supply management," *IEEE Internet Things J.*, vol. 9, no. 16, pp. 14247–14259, Aug. 2022.

[75] R. V. George, H. O. Harsh, P. Ray, and A. K. Babu, "Food quality traceability prototype for restaurants using blockchain and food quality data index," *J. Cleaner Prod.*, vol. 240, Dec. 2019, Art. no. 118021.

[76] A. Haroon, M. Basharat, A. M. Khattak, and W. Ejaz, "Internet of Things platform for transparency and traceability of food supply chain," in *Proc. IEEE 10th Annu. Inf. Technol., Electron. Mobile Commun. Conf. (IEMCON)*, Oct. 2019, pp. 13–19.

[77] H. Hayati and I. G. B. B. Nugraha, "Blockchain based traceability system in food supply chain," in *Proc. Int. Seminar Res. Inf. Technol. Intell. Syst. (ISRITI)*, Nov. 2018, pp. 120–125.

[78] W. Hong, Y. Cai, Z. Yu, and X. Yu, "An agri-product traceability system based on IoT and blockchain technology," in *Proc. 1st IEEE Int. Conf. Hot Inf.-Centric Netw. (HotICN)*, Aug. 2018, pp. 254–255.

[79] S. Hu, S. Huang, J. Huang, and J. Su, "Blockchain and edge computing technology enabling organic agricultural supply chain: A framework solution to trust crisis," *Comput. Ind. Eng.*, vol. 153, Mar. 2021, Art. no. 107079.

[80] J. Hua, X. Wang, M. Kang, H. Wang, and F.-Y. Wang, "Blockchain based provenance for agricultural products: A distributed platform with duplicated and shared bookkeeping," in *Proc. IEEE Intell. Vehicles Symp. (IV)*, Jun. 2018, pp. 97–101.

[81] J. Jaiyen, S. Pongnumkul, and P. Chaovalit, "A proof-of-concept of farmer-to-consumer food traceability on blockchain for local communities," in *Proc. Int. Conf. Comput. Sci. Appl. Agricult. (ICOSICA)*, Sep. 2020, pp. 1–5.

[82] H. Johng, D. Kim, T. Hill, and L. Chung, "Using blockchain to enhance the trustworthiness of business processes: A goal-oriented approach," in *Proc. IEEE Int. Conf. Services Comput. (SCC)*, Jul. 2018, pp. 249–252.

[83] S. S. Kamble, A. Gunasekaran, and R. Sharma, "Modeling the blockchain enabled traceability in agriculture supply chain," *Int. J. Inf. Manage.*, vol. 52, Jun. 2020, Art. no. 101967.

[84] M. Kim, B. Hilton, Z. Burks, and J. Reyes, "Integrating blockchain, smart contract-tokens, and IoT to design a food traceability solution," in *Proc. IEEE 9th Annu. Inf. Technol., Electron. Mobile Commun. Conf. (IEMCON)*, Nov. 2018, pp. 335–340.

[85] S. Köhler and M. Pizzol, "Technology assessment of blockchain-based technologies in the food supply chain," *J. Cleaner Prod.*, vol. 269, Oct. 2020, Art. no. 122193.

[86] J. Lai, L. Du, and Q. Li, "Information architecture design based on block chain technology," in *Proc. Int. Conf. Comput. Netw., Electron. Autom. (ICCNEA)*, Sep. 2020, pp. 185–190.

[87] M.-J. Lee, J.-T. Luo, J.-J. Shao, and N.-F. Huang, "A trustworthy food resume traceability system based on blockchain technology," in *Proc. Int. Conf. Inf. Netw. (ICOIN)*, Jan. 2021, pp. 546–552.

[88] J. Li and X. Wang, "Research on the application of blockchain in the traceability system of agricultural products," in *Proc. 2nd IEEE Adv. Inf. Manag., Communicates, Electron. Autom. Control Conf. (IMCEC)*, May 2018, pp. 2637–2640.

[89] Q. Lin, H. Wang, X. Pei, and J. Wang, "Food safety traceability system based on blockchain and EPCIS," *IEEE Access*, vol. 7, pp. 20698–20707, 2019.

[90] W. Lin, X. Huang, H. Fang, V. Wang, Y. Hua, J. Wang, H. Yin, D. Yi, and L. Yau, "Blockchain technology in current agricultural systems: From techniques to applications," *IEEE Access*, vol. 8, pp. 143920–143937, 2020.

[91] K. S. Loke and O. C. Ann, "Food traceability and prevention of location fraud using blockchain," in *Proc. IEEE 8th R10 Humanitarian Technol. Conf. (R10-HTC)*, Dec. 2020, pp. 1–5.

[92] T. B. Machado, L. Ricciardi, and M. Beatriz P P Oliveira, "Blockchain technology for the management of food sciences researches," *Trends Food Sci. Technol.*, vol. 102, pp. 261–270, Aug. 2020.

[93] S. Madumidha, P. S. Ranjani, U. Vandhana, and B. Venmuhilan, "A theoretical implementation: Agriculture-food supply chain management using blockchain technology," in *Proc. TEQIP III Sponsored Int. Conf. Microw. Integr. Circuits, Photon. Wireless Netw. (IMICPW)*, May 2019, pp. 174–178.

[94] M. Maity, A. Tolooie, A. K. Sinha, and M. K. Tiwari, "Stochastic batch dispersion model to optimize traceability and enhance transparency using blockchain," *Comput. Ind. Eng.*, vol. 154, Apr. 2021, Art. no. 107134.

[95] S. Malik, S. S. Kanhere, and R. Jurdak, "ProductChain: Scalable blockchain framework to support provenance in supply chains," in *Proc. IEEE 17th Int. Symp. Netw. Comput. Appl. (NCA)*, Nov. 2018, pp. 1–10.

[96] S. K. Mangla, Y. Kazancoglu, E. Ekinci, M. Liu, M. Özbiltekin, and M. D. Sezer, "Using system dynamics to analyze the societal impacts of blockchain technology in milk supply chainsrefer," *Transp. Res. E, Logistics Transp. Rev.*, vol. 149, May 2021, Art. no. 102289.

[97] D.-H. Nguyen, N. H. Tuong, and H.-A. Pham, "Blockchain-based farming activities tracker for enhancing trust in the community supported agriculture model," in *Proc. Int. Conf. Inf. Commun. Technol. Converg. (ICTC)*, Oct. 2020, pp. 737–740.

[98] P. S, Meeradevi, and M. R. Mundada, "Analysis of agricultural supply chain management for traceability of food products using blockchain-Ethereum technology," in *Proc. IEEE Int. Conf. Distrib. Comput., VLSI, Electr. Circuits Robot. (DISCOVER)*, Oct. 2020, pp. 127–132.

[99] A. Pal and K. Kant, "Using blockchain for provenance and traceability in Internet of Things-integrated food logistics," *Computer*, vol. 52, no. 12, pp. 94–98, Dec. 2019.

[100] D. Pérez, R. Risco, and L. Casaverde, "Analysis of the implementation of blockchain as a mechanism for digital and transparent food traceability in Peruvian social programs," in *Proc. IEEE 27th Int. Conf. Electron., Electr. Eng. Comput. (INTERCON)*, Sep. 2020, pp. 1–4.

[101] I. G. M. T. Pradana, T. Djatna, and I. Hermadi, "Blockchain modeling for traceability information system in supply chain of coffee agroindustry," in *Proc. Int. Conf. Adv. Comput. Sci. Inf. Syst. (ICACSIS)*, Oct. 2020, pp. 217–224.

[102] J. Qian, W. Wu, Q. Yu, L. Ruiz-Garcia, Y. Xiang, L. Jiang, Y. Shi, Y. Duan, and P. Yang, "Filling the trust gap of food safety in food trade between the EU and China: An interconnected conceptual traceability framework based on blockchain," *Food Energy Secur.*, vol. 9, no. 4, Nov. 2020, Art. no. e249.

[103] M. A. S. Rünzel, E. E. Hassler, R. E. L. Rogers, G. Formato, and J. A. Cazier, "Designing a smart honey supply chain for sustainable development," *IEEE Consum. Electron. Mag.*, vol. 10, no. 4, pp. 69–78, Jul. 2021.

[104] B. Saiharsha, R. S. S. Tharagesh, S. V. N. Kumar, and N. Harini, "Cloud based data integrity model for minimal human intervention using smart contracts," in *Proc. 5th Int. Conf. Commun. Electron. Syst. (ICCES)*, Jun. 2020, pp. 910–916.

[105] K. Salah, N. Nizamuddin, R. Jayaraman, and M. Omar, "Blockchain-based soybean traceability in agricultural supply chain," *IEEE Access*, vol. 7, pp. 73295–73305, 2019.

[106] S. Saurabh and K. Dey, "Blockchain technology adoption, architecture, and sustainable agri-food supply chains," *J. Cleaner Prod.*, vol. 284, Feb. 2021, Art. no. 124731.

[107] S. Shaikh, M. Butala, R. Butala, and M. Creado, "AgroVita using blockchain," in *Proc. IEEE 5th Int. Conf. Converg. Technol. (I2CT)*, Mar. 2019, pp. 1–5.

[108] S. Stranieri, F. Riccardi, M. P. M. Meuwissen, and C. Soregaroli, "Exploring the impact of blockchain on the performance of agri-food supply chains," *Food Control*, vol. 119, Jan. 2021, Art. no. 107495.

[109] Y. P. Tsang, K. L. Choy, C. H. Wu, G. T. S. Ho, and H. Y. Lam, "Blockchain-driven IoT for food traceability with an integrated consensus mechanism," *IEEE Access*, vol. 7, pp. 129000–129017, 2019.

[110] D. Tse, B. Zhang, Y. Yang, C. Cheng, and H. Mu, "Blockchain application in food supply information security," in *Proc. IEEE Int. Conf. Ind. Eng. Eng. Manage. (IEEM)*, Dec. 2017, pp. 1357–1361.

[111] N. Tsolakis, D. Niedenzu, M. Simonetto, M. Dora, and M. Kumar, "Supply network design to address united nations sustainable development goals: A case study of blockchain implementation in Thai fish industry," *J. Bus. Res.*, vol. 131, pp. 495–519, Jul. 2021.

[112] A. Vangala, A. K. Das, N. Kumar, and M. Alazab, "Smart secure sensing for IoT-based agriculture: Blockchain perspective," *IEEE Sensors J.*, vol. 21, no. 16, pp. 17591–17607, Aug. 2021.

[113] A. Vangala, A. K. Sutrala, A. K. Das, and M. Jo, "Smart contract-based blockchain-envisioned authentication scheme for smart farming," *IEEE Internet Things J.*, vol. 8, no. 13, pp. 10792–10806, Jul. 2021.

[114] S. Voulgaris, N. Fotiou, V. A. Siris, G. C. Polyzos, A. Tomaras, and S. Karachontzitis, "Hierarchical blockchain topologies for quality control in food supply chains," in *Proc. Eur. Conf. Netw. Commun. (EuCNC)*, Jun. 2020, pp. 139–143.

[115] L. Wang, L. Xu, Z. Zheng, S. Liu, X. Li, L. Cao, J. Li, and C. Sun, "Smart contract-based agricultural food supply chain traceability," *IEEE Access*, vol. 9, pp. 9296–9307, 2021.

[116] S. Wang, D. Li, Y. Zhang, and J. Chen, "Smart contract-based product traceability system in the supply chain scenario," *IEEE Access*, vol. 7, pp. 115122–115133, 2019.

[117] W. Xie, X. Zheng, X. Lu, X. Lin, and X. Fan, "Agricultural product traceability system based on blockchain technology," in *Proc. IEEE Int. Conf Parallel Distrib. Process. With Appl., Big Data Cloud Comput., Sustain. Comput. Commun., Social Comput. Netw. (ISPA/BDCloud/SocialCom/SustainCom)*, Dec. 2019, pp. 1266–1270.

[118] L. Yang, X.-Y. Liu, and J. S. Kim, "Cloud-based livestock monitoring system using RFID and blockchain technology," in *Proc. 7th IEEE Int. Conf. Cyber Secur. Cloud Comput. (CSCloud)/ 6th IEEE Int. Conf. Edge Comput. Scalable Cloud (EdgeCom)*, Aug. 2020, pp. 240–245.

[119] X. Yang, M. Li, H. Yu, M. Wang, D. Xu, and C. Sun, "A trusted blockchain-based traceability system for fruit and vegetable agricultural products," *IEEE Access*, vol. 9, pp. 36282–36293, 2021.

[120] J.-Y. Yeh, S.-C. Liao, Y.-T. Wang, and Y.-J. Chen, "Understanding consumer purchase intention in a blockchain technology for food traceability and transparency context," in *Proc. IEEE Social Implications Technol. (SIT) Inf. Manage. (SITIM)*, Nov. 2019, pp. 1–6.

[121] W. Yu and S. Huang, "Traceability of food safety based on block chain and RFID technology," in *Proc. 11th Int. Symp. Comput. Intell. Design (ISCID)*, vol. 1, Dec. 2018, pp. 339–342.

[122] X. Zhang, P. Sun, J. Xu, X. Wang, J. Yu, Z. Zhao, and Y. Dong, "Blockchain-based safety management system for the grain supply chain," *IEEE Access*, vol. 8, pp. 36398–36410, 2020.

[123] I. Petek and N. Zajec, "Collaborative intelligence and decentralized business community building–potentials in Food/Nutrition sector," in *Proc. IEEE 34th Int. Conf. Data Eng. Workshops (ICDEW)*, Apr. 2018, pp. 150–153.

[124] G. Baralla, S. Ibba, M. Marchesi, R. Tonelli, and S. Missineo, "A blockchain based system to ensure transparency and reliability in food supply chain," in *Proc. Eur. Conf. Parallel Process.* Cham, Switzerland: Springer, 2018, pp. 379–391.

[125] B. M. A. L. Basnayake and C. Rajapakse, "A blockchain-based decentralized system to ensure the transparency of organic food supply chain," in *Proc. Int. Res. Conf. Smart Comput. Syst. Eng. (SCSE)*, Mar. 2019, pp. 103–107.

[126] S. Aich, S. Chakraborty, M. Sain, H.-I. Lee, and H.-C. Kim, "A review on benefits of IoT integrated blockchain based supply chain management implementations across different sectors with case study," in *Proc. 21st Int. Conf. Adv. Commun. Technol. (ICACT)*, Feb. 2019, pp. 138–141.

[127] N. Kshetri, "Blockchain and the economics of food safety," *IT Prof.*, vol. 21, no. 3, pp. 63–66, May 2019.

[128] D. Shakhbulatov, A. Arora, Z. Dong, and R. Rojas-Cessa, "Blockchain implementation for analysis of carbon footprint across food supply chain," in *Proc. IEEE Int. Conf. Blockchain (Blockchain)*, Jul. 2019, pp. 546–551.

[129] S. Mondal, K. P. Wijewardena, S. Karuppuswami, N. Kriti, D. Kumar, and P. Chahal, "Blockchain inspired RFID-based information architecture for food supply chain," *IEEE Internet Things J.*, vol. 6, no. 3, pp. 5803–5813, Jun. 2019.

[130] G. R. Chandra, I. A. Liaqat, and B. Sharma, "Blockchain redefining: The halal food sector," in *Proc. Amity Int. Conf. Artif. Intell. (AICAI)*, Feb. 2019, pp. 349–354.

[131] R. M. A. Latif, S. Iqbal, O. Rizwan, S. U. A. Shah, M. Farhan, and F. Ijaz, "Blockchain transforms the retail level by using a supply chain rules and regulation," in *Proc. 2nd Int. Conf. Commun., Comput. Digit. Syst. (C-CODE)*, Mar. 2019, pp. 264–269.

[132] H. Wu, J. Cao, Y. Yang, C. L. Tung, S. Jiang, B. Tang, Y. Liu, X. Wang, and Y. Deng, "Data management in supply chain using blockchain: Challenges and a case study," in *Proc. 28th Int. Conf. Comput. Commun. Netw. (ICCCN)*, Jul. 2019, pp. 1–8.

[133] Q. Tao, X. Cui, X. Huang, A. M. Leigh, and H. Gu, "Food safety supervision system based on hierarchical multi-domain blockchain network," *IEEE Access*, vol. 7, pp. 51817–51826, 2019.

[134] H. Huang, X. Zhou, and J. Liu, "Food supply chain traceability scheme based on blockchain and EPC technology," in *Proc. Int. Conf. Smart Blockchain*. Cham, Switzerland: Springer, 2019, pp. 32–42.

[135] M. Markovic, P. Edwards, and N. Jacobs, "Recording provenance of food delivery using IoT, semantics and business blockchain networks," in *Proc. 6th Int. Conf. Internet Things, Syst., Manage. Secur. (IOTSMS)*, Oct. 2019, pp. 116–118.

[136] A. Kamilaris, A. Fonts, and F. X. Prenafeta-Boldú, "The rise of blockchain technology in agriculture and food supply chains," *Trends Food Sci. Technol.*, vol. 91, pp. 640–652, Sep. 2019.

[137] S. Madumidha, P. S. Ranjani, S. S. Varsinee, and P. S. Sundari, "Transparency and traceability: In food supply chain system using blockchain technology with Internet of Things," in *Proc. 3rd Int. Conf. Trends Electron. Informat. (ICOEI)*, Apr. 2019, pp. 983–987.

[138] N. Kumar S. V., S. Balasubramaniam, R. S. Tharagesh, P. Kumar, and B. Janavi, "An autonomous food wastage control warehouse: Distributed ledger and machine learning based approach," in *Proc. 11th Int. Conf. Comput., Commun. Netw. Technol. (ICCCNT)*, Jul. 2020, pp. 1–6.

[139] S. H. Awan, A. Nawaz, S. Ahmed, H. A. Khattak, K. Zaman, and Z. Najam, "Blockchain based smart model for agricultural food supply chain," in *Proc. Int. Conf. U.K.-China Emerg. Technol. (UCET)*, Aug. 2020, pp. 1–5.

[140] S. Thejaswini and K. R. Ranjitha, "Blockchain in agriculture by using decentralized peer to peer networks," in *Proc. 4th Int. Conf. Inventive Syst. Control (ICISC)*, Jan. 2020, pp. 600–606.

[141] P. Dutta, T.-M. Choi, S. Somani, and R. Butala, "Blockchain technology in supply chain operations: Applications, challenges and research opportunities," *Transp. Res. E, Logistics Transp. Rev.*, vol. 142, Oct. 2020, Art. no. 102067.

[142] R. Miron, M. Hulea, and S. Folea, "Food allergens monitoring system backed-up by blockchain technology," in *Proc. IEEE Int. Conf. Autom., Quality Test., Robot. (AQTR)*, May 2020, pp. 1–4.

[143] B. Yu, P. Zhan, M. Lei, F. Zhou, and P. Wang, "Food quality monitoring system based on smart contracts and evaluation models," *IEEE Access*, vol. 8, pp. 12479–12490, 2020.

[144] A. Biscotti, C. Giannelli, C. F. N. Keyi, R. Lazzarini, A. Sardone, C. Stefanelli, and G. Virgilli, "Internet of Things and blockchain technologies for food safety systems," in *Proc. IEEE Int. Conf. Smart Comput. (SMARTCOMP)*, Sep. 2020, pp. 440–445.

[145] L. Hou, R. Liao, and Q. Luo, "IoT and blockchain-based smart agri-food supply chains," in *Handbook Smart Cities*, 2020, pp. 1–22.

[146] N. N. Ahamed, P. Karthikeyan, S. P. Anandaraj, and R. Vignesh, "Sea food supply chain management using blockchain," in *Proc. 6th Int. Conf. Adv. Comput. Commun. Syst. (ICACCS)*, Mar. 2020, pp. 473–476.

[147] N. Kshetri and J. DeFranco, "The economics behind food supply blockchains," *Computer*, vol. 53, no. 12, pp. 106–110, Dec. 2020.

[148] C. Stach, C. Gritti, D. Przytarski, and B. Mitschang, "Trustworthy, secure, and privacy-aware food monitoring enabled by blockchains and the IoT," in *Proc. IEEE Int. Conf. Pervasive Comput. Commun. Workshops (PerCom Workshops)*, Mar. 2020, pp. 1–4.

[149] F. M. Enescu and V. M. Ionescu, "Using blockchain in the agri-food sector following SARS-CoV-2 pandemic," in *Proc. 12th Int. Conf. Electron., Comput. Artif. Intell. (ECAI)*, Jun. 2020, pp. 1–6.

[150] V. Sudha, R. Kalaiselvi, and P. Shanmughasundaram, "Blockchain based solution to improve the supply chain management in Indian agriculture," in *Proc. Int. Conf. Artif. Intell. Smart Syst. (ICAIS)*, Mar. 2021, pp. 1289–1292.

[151] H. P. A, M. Senthilmurugan, K. P. Rahul, and R. Chinnaiyan, "IoT and machine learning based peer to peer platform for crop growth and disease monitoring system using blockchain," in *Proc. Int. Conf. Comput. Commun. Informat. (ICCCI)*, Jan. 2021, pp. 1–5.

[152] S. Yasmin, M. F. A. A. Sohan, M. N. B. Anwar, M. Hasan, and G. M. F. Hossain, "SFC: A lightweight blockchain model for smart food industry," in *Proc. 2nd Int. Conf. Robot., Electr. Signal Process. Techn. (ICREST)*, Jan. 2021, pp. 699–703.

[153] S. Al-Amin, S. R. Sharkar, M. S. Kaiser, and M. Biswas, "Towards a blockchain-based supply chain management for e-agro business system," in *Proc. Int. Conf. Trends Comput. Cognit. Eng.* Cham, Switzerland: Springer, 2021, pp. 329–339.

[154] L. Marchesi, M. Marchesi, R. Tonelli, and M. I. Lunesu, "A blockchain architecture for industrial applications," *Blockchain, Res. Appl.*, vol. 3, no. 4, Dec. 2022, Art. no. 100088.

[155] A. Marchese and O. Tomarchio, "A blockchain-based system for agri-food supply chain traceability management," *Social Netw. Comput. Sci.*, vol. 3, no. 4, pp. 1–21, May 2022.

[156] S. K. Mangla, Y. Kazançoğlu, A. Yıldızbaşı, C. Öztürk, and A. Çalık, "A conceptual framework for blockchain-based sustainable supply chain and evaluating implementation barriers: A case of the tea supply chain," *Bus. Strategy Environ.*, vol. 31, no. 8, pp. 3693–3716, Dec. 2022.

[157] I. Ehsan, M. I. Khalid, L. Ricci, J. Iqbal, A. Alabrah, S. S. Ullah, and T. M. Alfakih, "A conceptual model for blockchain-based agriculture food supply chain system," *Sci. Program.*, vol. 2022, pp. 1–15, Feb. 2022.

[158] Y. Lu, P. Li, and H. Xu, "A food anti-counterfeiting traceability system based on blockchain and Internet of Things," *Proc. Comput. Sci.*, vol. 199, pp. 629–636, Jan. 2022.

[159] F. A. Mileti, P. Miranda, G. Langella, M. Pacciarelli, C. D. Michele, P. Manna, M. Bancheri, and F. Terribile, "A geospatial decision support system for ecotourism: A case study in the Campania region of Italy," *Land Use Policy*, vol. 118, Jul. 2022, Art. no. 106131.

[160] B. Bigliardi, E. Bottani, and S. Filippelli, "A study on IoT application in the food industry using keywords analysis," *Proc. Comput. Sci.*, vol. 200, pp. 1826–1835, Jan. 2022.

[161] Q. Tao, Z. Cai, and X. Cui, "A technological quality control system for Rice supply chain," *Food Energy Secur.*, vol. 12, no. 2, Mar. 2023, Art. no. e382.

[162] M. E. Latino, M. Menegoli, and A. Corallo, "Agriculture digitalization: A global examination based on bibliometric analysis," *IEEE Trans. Eng. Manag.*, early access, Mar. 30, 2022, doi: 10.1109/TEM.2022.3154841.

[163] X. Cui and Z. Gao, "Application of Internet of Things and traceability technology in the whole industrial chain in mountainous areas by blockchain," in *Proc. IEEE 2nd Int. Conf. Power, Electron. Comput. Appl. (ICPECA)*, Jan. 2022, pp. 720–723.

[164] L. Marchesi, K. Mannaro, M. Marchesi, and R. Tonelli, "Automatic generation of Ethereum-based smart contracts for agri-food traceability system," *IEEE Access*, vol. 10, pp. 50363–50383, 2022.

[165] Y. Zhang, L. Chen, M. Battino, M. A. Farag, J. Xiao, J. Simal-Gandara, H. Gao, and W. Jiang, "Blockchain: An emerging novel technology to upgrade the current fresh fruit supply chain," *Trends Food Sci. Technol.*, vol. 124, pp. 1–12, Jun. 2022.

[166] P. Burgess, F. Sunmola, and S. Wertheim-Heck, "Blockchain enabled quality management in short food supply chains," *Proc. Comput. Sci.*, vol. 200, pp. 904–913, Jan. 2022.

[167] S. L. Bager, C. Singh, and U. M. Persson, "Blockchain is not a silver bullet for agro-food supply chain sustainability: Insights from a coffee case study," *Current Res. Environ. Sustainability*, vol. 4, Jan. 2022, Art. no. 100163.

[168] H. H. Khan, M. N. Malik, Z. Konečná, A. G. Chofreh, F. A. Goni, and J. J. Klemeš, "Blockchain technology for agricultural supply chains during the COVID-19 pandemic: Benefits and cleaner solutions," *J. Cleaner Prod.*, vol. 347, May 2022, Art. no. 131268.

[169] Q. Luo, R. Liao, J. Li, X. Ye, and S. Chen, "Blockchain enabled credibility applications: Extant issues, frameworks and cases," *IEEE Access*, vol. 10, pp. 45759–45771, 2022.

[170] S. Bökle, D. S. Paraforos, D. Reiser, and H. W. Griepentrog, "Conceptual framework of a decentral digital farming system for resilient and safe data management," *Smart Agricult. Technol.*, vol. 2, Dec. 2022, Art. no. 100039.

[171] B. Subashini and D. Hemavathi, "Detecting the traceability issues in supply chain industries using blockchain technology," in *Proc. Int. Conf. Adv. Comput., Commun. Appl. Informat. (ACCAI)*, Jan. 2022, pp. 1–8.

[172] A. Ferrari, M. Bacco, K. Gaber, A. Jedlitschka, S. Hess, J. Kaipainen, P. Koltsida, E. Toli, and G. Brunori, "Drivers, barriers and impacts of digitalisation in rural areas from the viewpoint of experts," *Inf. Softw. Technol.*, vol. 145, May 2022, Art. no. 106816.

[173] A. Moretto and L. Macchion, "Drivers, barriers and supply chain variables influencing the adoption of the blockchain to support traceability along fashion supply chains," *Oper. Manage. Res.*, vol. 15, pp. 1470–1489, Mar. 2022.

[174] A. Kowalska and L. Manning, "Food safety governance and guardianship: The role of the private sector in addressing the EU ethylene oxide incident," *Foods*, vol. 11, no. 2, p. 204, Jan. 2022.

[175] E. S. Rao, S. Shukla, and Rizwana, "Food traceability system in India," *Meas., Food*, vol. 5, Feb. 2022, Art. no. 100019.

[176] S. Jin, W. Li, Y. Cao, G. Jones, J. Chen, Z. Li, Q. Chang, G. Yang, and L. J. Frewer, "Identifying barriers to sustainable apple production: A stakeholder perspective," *J. Environ. Manage.*, vol. 302, Jan. 2022, Art. no. 114082.

[177] G. P. Agnusdei, B. Coluccia, V. Elia, and P. P. Miglietta, "IoT technologies for wine supply chain traceability: Potential application in the Southern Apulia Region (Italy)," *Proc. Comput. Sci.*, vol. 200, pp. 1125–1134, Jan. 2022.

[178] C. Chauhan, V. Parida, and A. Dhir, "Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises," *Technolog. Forecasting Social Change*, vol. 177, Apr. 2022, Art. no. 121508.

[179] G. Kannan, M. Pattnaik, G. Karthikeyan, E. Balamurugan, P. J. Augustine, and J. J. Lohith, "Managing the supply chain for the crops directed from agricultural fields using blockchains," in *Proc. Int. Conf. Electron. Renew. Syst. (ICEARS)*, Mar. 2022, pp. 908–913.

[180] B. Niu, J. Dong, Z. Dai, and J. Y. Jin, "Market expansion vs. intensified competition: Overseas supplier's adoption of blockchain in a cross-border agricultural supply chain," *Electron. Commerce Res. Appl.*, vol. 51, Jan. 2022, Art. no. 101113.

[181] D. Ravi, S. Ramachandran, R. Vignesh, V. R. Falmari, and M. Brindha, "Privacy preserving transparent supply chain management through hyperledger fabric," *Blockchain, Res. Appl.*, vol. 3, no. 2, Jun. 2022, Art. no. 100072.

[182] N. Singh and P. Bagade, "Quality, food safety and role of technology in food industry," in *Thermal Food Engineering Operations*, 2022, pp. 415–454.

[183] M. Akhtaruzzaman Khan, M. E. Hossain, A. Shahaab, and I. Khan, "ShrimpChain: A blockchain-based transparent and traceable framework to enhance the export potentiality of Bangladeshi shrimp," *Smart Agricult. Technol.*, vol. 2, Dec. 2022, Art. no. 100041.

[184] A. Egwuonwu, C. Mordi, A. Egwuonwu, and O. Uadiale, "The influence of blockchains and Internet of Things on global value chain," *Strategic Change*, vol. 31, no. 1, pp. 45–55, Jan. 2022.

[185] F. Anastasiadis, I. Manikas, I. Apostolidou, and S. Wahbeh, "The role of traceability in end-to-end circular agri-food supply chains," *Ind. Marketing Manage.*, vol. 104, pp. 196–211, Jul. 2022.

[186] K. Bala and P. D. Kaur, "Transparent subsidized agri-product distribution during pandemics with reputation based PoA blockchain," *Concurrency Comput., Pract. Exper.*, vol. 34, no. 22, Oct. 2022, Art. no. e6863

[187] V. S. Narwane, A. Gunasekaran, and B. B. Gardas, "Unlocking adoption challenges of IoT in Indian agricultural and food supply chain," *Smart Agricult. Technol.*, vol. 2, Dec. 2022, Art. no. 100035.

[188] H. Treiblmaier and M. Garaus, "Using blockchain to signal quality in the food supply chain: The impact on consumer purchase intentions and the moderating effect of brand familiarity," *Int. J. Inf. Manage.*, vol. 68, Feb. 2023, Art. no. 102514.

[189] M. E. Latino, M. Menegoli, M. Lazoi, and A. Corallo, "Voluntary traceability in food supply chain: A framework leading its implementation in agriculture 4.0," *Technolog. Forecasting Social Change*, vol. 178, May 2022, Art. no. 121564.

[190] L. Compagnucci, D. Lepore, F. Spigarelli, E. Frontoni, M. Baldi, and L. D. Berardino, "Uncovering the potential of blockchain in the agri-food supply chain: An interdisciplinary case study," *J. Eng. Technol. Manage.*, vol. 65, Jul. 2022, Art. no. 101700.

[191] A. H. Adow, M. K. Shrivas, H. F. Mahdi, M. M. A. Zahra, D. Verma, N. V. Doohan, and A. Jalali, "Analysis of agriculture and food supply chain through blockchain and IoT with light weight cluster head," *Comput. Intell. Neurosci.*, vol. 2022, pp. 1–11, Aug. 2022.

[192] S. Cao, M. Foth, W. Powell, T. Miller, and M. Li, "A blockchain-based multisignature approach for supply chain governance: A use case from the Australian beef industry," *Blockchain, Res. Appl.*, vol. 3, no. 4, Dec. 2022, Art. no. 100091.

[193] J. D. Sekuloska and A. Erceg, "Blockchain technology toward creating a smart local food supply chain," *Computers*, vol. 11, no. 6, p. 95, Jun. 2022.

[194] Q. Zhai, A. Sher, and Q. Li, "The impact of health risk perception on blockchain traceable fresh fruits purchase intention in China," *Int. J. Environ. Res. Public Health*, vol. 19, no. 13, p. 7917, Jun. 2022.

[195] M. Lei, S. Liu, N. Luo, X. Yang, and C. Sun, "Trusted-auditing chain: A security blockchain prototype used in agriculture traceability," *Heliyon*, vol. 8, no. 11, Nov. 2022, Art. no. e11477.

[196] O. Okorie, J. Russell, Y. Jin, C. Turner, Y. Wang, and F. Charnley, "Removing barriers to blockchain use in circular food supply chains: Practitioner views on achieving operational effectiveness," *Cleaner Logistics Supply Chain*, vol. 5, Dec. 2022, Art. no. 100087.

[197] R. Bettín-Díaz, A. E. Rojas, and C. Mejía-Moncayo, "Colombian origin coffee supply chain traceability by a blockchain implementation," *Oper. Res. Forum*, vol. 3, p. 64, Nov. 2022.

[198] A. Pakseresht, A. Yavari, S. A. Kaliji, and K. Hakelius, "The intersection of blockchain technology and circular economy in the agri-food sector," *Sustain. Prod. Consumption*, vol. 35, pp. 260–274, Jan. 2023.
[199] A. Singh, A. Gutub, A. Nayyar, and M. K. Khan, "Redefining food safety traceability system through blockchain: Findings, challenges and open issues," *Multimedia Tools Appl.*, vol. 82, pp. 21243–21277, Oct. 2022.
[200] J. Ktari, T. Frikha, F. Chaabane, M. Hamdi, and H. Hamam, "Agricultural lightweight embedded blockchain system: A case study in olive oil," *Electronics*, vol. 11, no. 20, p. 3394, Oct. 2022.
[201] R. Parvathi, M. Girish, M. G. Sandeep, and K. Abhiram, "Secured blockchain technology for agriculture food supply chain," *J. Pharmaceutical Negative Results*, pp. 357–361, Sep. 2022.
[202] A. Tharatipyakul, S. Pongnumkul, N. Riansumrit, S. Kingchan, and S. Pongnumkul, "Blockchain-based traceability system from the users' perspective: A case study of Thai coffee supply chain," *IEEE Access*, vol. 10, pp. 98783–98802, 2022.
[203] P. Liu, Z. Zhang, and Y. Li, "Investment decision of blockchain-based traceability service input for a competitive agri-food supply chain," *Foods*, vol. 11, no. 19, p. 2981, Sep. 2022.
[204] F.-J. Ferrández-Pastor, J. Mora-Pascual, and D. Díaz-Lajara, "Agricultural traceability model based on IoT and blockchain: Application in industrial hemp production," *J. Ind. Inf. Integr.*, vol. 29, Sep. 2022, Art. no. 100381.

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