

Review

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Review

Blockchain Technology in Agriculture: Ensuring Transparency and Traceability in the Food Supply Chain

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Abstract: This research explores the role of transparency and traceability in the agricultural food supply chain. By utilizing blockchain's decentralized and secure features, stakeholders can improve information sharing from farm to consumer, transparency and traceability issues. Real-world examples illustrate blockchain's successful application in agriculture, boosting transparency, efficiency, and trust and create immutable records, enhance visibility, and provide reliable data, while combating fraud and promoting sustainability. It also examines blockchain's impact on food safety through IoT and smart contracts, highlighting successful implementations in supply chain management, the research underscores blockchain's potential to build consumer trust in food safety, quality, and origin.

Keywords: blockchain; smart contract; IoT; agriculture; supply chain; transparent; secure; traceability; agricultural supply chain

Introduction

In the agricultural sector, it is crucial to prioritize transparency and traceability in the food supply chain ([Demestichas et al., 2020](#))The adoption of blockchain technology enables stakeholders to effectively document and access every stage of the process, ensuring accuracy from farm to table. Blockchain technology offers a promising solution to tackle the obstacles and intricacies linked with achieving transparency and traceability in the food supply chain. Through harnessing the decentralization, security, immutability, and smart contract features of blockchain, the agricultural industry can transform the way information is documented and shared.

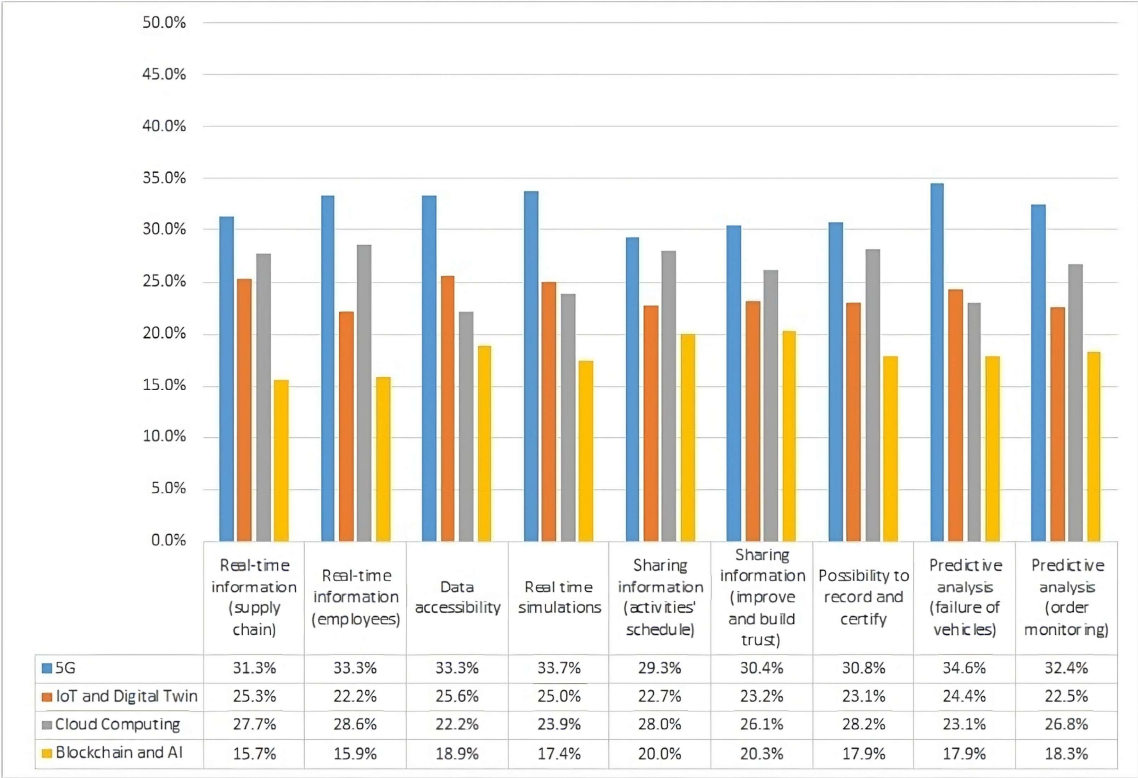


Figure 1. Source : (Apuzzese et al., 2023).

Keyword Selection

This review followed the strategy suggested by (Talwar et al., 2020)for identifying keyword for article search .accordingly as a first step a search was performed via the Google Scholar platform using "blockchain" as a search word. Next, the papers within the first 100 results were downloaded and screened. Their titles, abstracts and keywords were assessed to generate a new list of keywords for this review's literature search.

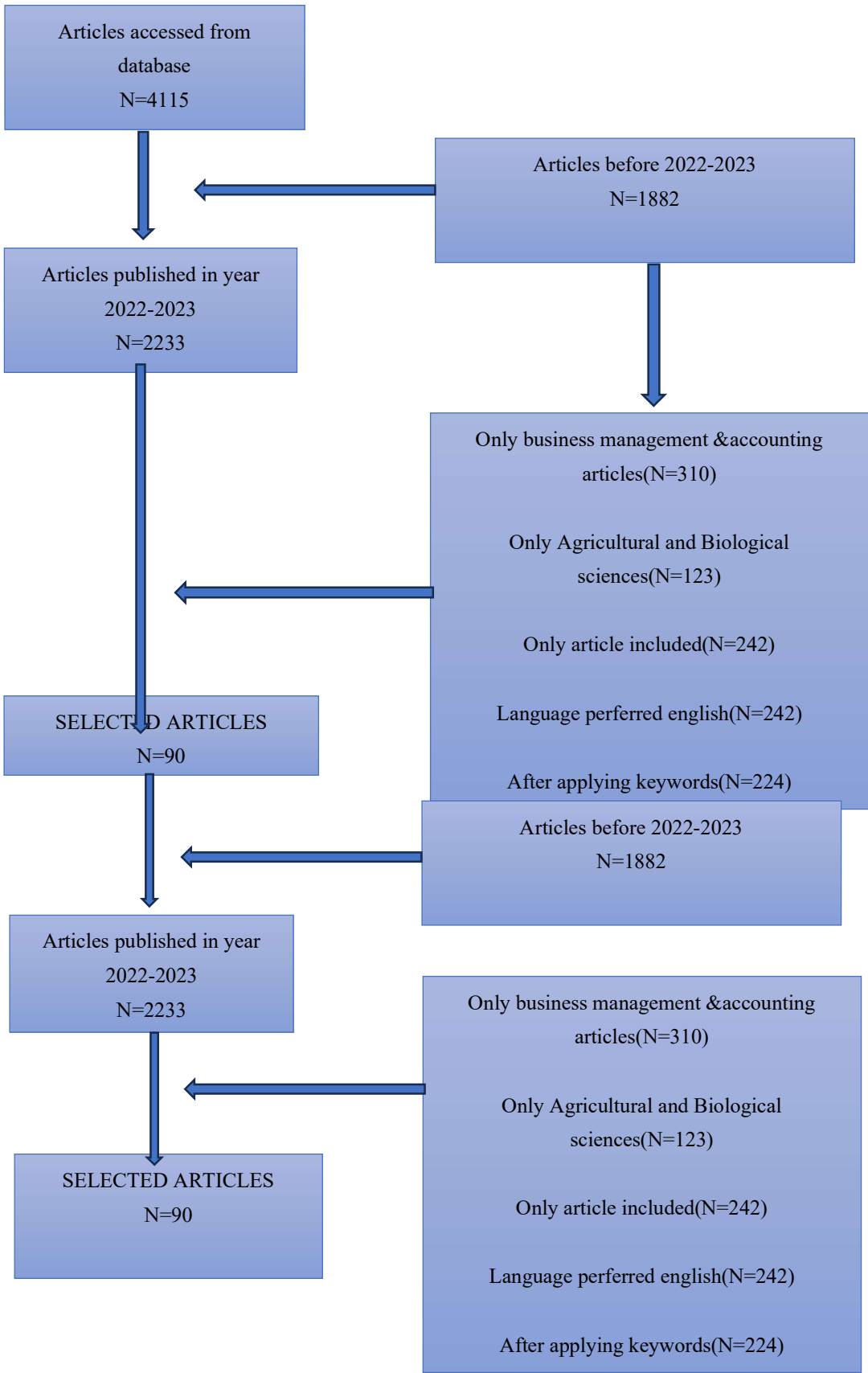
Based on the screening results, it was found that the most frequently used keywords in the papers titles, abstracts and keyword lists are 'blockchain ', 'traceability', 'Agricultural supply chain', 'blockchain technology', 'food traceability '.Thus, these keywords were collected and used to search for relevant papers across all the databases.

Journal Selection And Inclusion/Exclusion Criteria

To select relevant academic articles for this review, inclusion and exclusion criteria were outlined consistent with past research (Nanda & Banerjee, 2021)accordingly, an article eligible for this review should (1) be a scholarly work, (2) be written in english, (3) be published in a peer-reviewed journal and (4) have a focus on blockchain technology. Additionally, to ensure the quality of the journals, consistent with previous systematic review papers (Goyal & Kumar, 2021), the australian business dean council (abdc) journal quality list and impact factor in journal citation reports (jcr) were used as proxies. Accordingly, papers were considered for this review only if published in journals listed as a or a*.abdc or journals with an impact factor of one or above in jcr.

The initial search of selected databases using specified keywords yielded a total of 4115 papers.only business management &accounting articles(n=310).only agricultural and biological sciences(n=123).then, inclusion and exclusion criteria were employed for the remaining 433 papers. The first criterion was to remove non-scholarly work. Non-scholarly work is publications in non-academic sources (e.g., newspapers, blogs, and trade journals). Therefore, 159 papers from non-scholarly sources were removed.

Further, as per the second criterion, only articles written in English 242 were selected . After that open access article only selected out of 242 only 98 are open source. After further inclusion only 90 articles are final.



Inclusion and exclusion criteria steps.

Descriptive Findings

This indicates sources (AJG 3 and later journals) that have published articles on the subject. Of all these sources, Annals of Operations Research contributed the most (13 articles), followed by Production Planning and Control (10), International Journal of Production Research (9), and Supply Chain Management: An International Journal (8) and IEEE. Transactions on Engineering Management and Transportation Research Part E: Logistics and Transportation Review, each of which produced 6 publications during the study period. International Journal of Production Economics, International Journal of Operations and Production Management and Journal of Business Logistics published 5 articles. The articles on production and operations management and Omega are the fewest among the journals, and each journal has only one issue related to the topic during the research period. Journal distribution also suggests that the application of blockchain in SCM is an attractive research topic for operations management and operations research.(Zhang et al., 2024)



Figure 2. Source : (Zhang et al., 2024).

Understanding Block Chain Technology in Agriculture

In the context of today's globalized food supply chain, the importance of transparency and traceability cannot be overstated. This holds true for consumers, regulators, and businesses alike. By integrating blockchain technology into the agricultural sector, we can establish a system that ensures the secure and transparent tracking of food products from their origin on the farm to their consumption by the end consumer .(Zhao et al., 2019) The implementation of blockchain technology enables the recording of every transaction and movement of food products on a decentralized digital ledger, guaranteeing that the information remains unaltered and cannot be manipulated. Blockchain technology presents a promising solution to this challenge by offering a decentralized, immutable, and transparent ledger system that can effectively monitor and verify each stage of the food supply chain . From the production phase to distribution, blockchain can capture and store crucial data such as the source of ingredients, farming techniques, transportation specifics, processing methods, and storage conditions. This ensures that such information is accurately recorded, securely stored, and accessible to all relevant parties. The level of transparency and traceability provided by blockchain not only fosters trust between consumers and producers but also facilitates more efficient implementation of food safety measures, recall management, and quality control processes .(Feng et al., 2020) Moreover, blockchain technology can effectively address issues related to fraud and counterfeit products within the agricultural sector .(Demestichas & Daskalakis, 2020; Demestichas et al., 2020) By utilizing blockchain technology, data pertaining to the food supply chain can be securely stored and accessed, creating an immutable record that cannot be tampered with. This level of data immutability and transparency plays a crucial role in verifying the authenticity and quality of

agricultural products, thereby preventing fraud and safeguarding consumers. Additionally, the integration of blockchain technology in agriculture has the potential to revolutionize the way farmers and other stakeholders interact and conduct business.

Enhancing Food Supply Chain Transparency through Blockchain

The utilization of blockchain technology presents a promising solution for enhancing transparency in the food supply chain by offering immutability, improved visibility, and data integrity. (Treiblmaier et al., 2020) With blockchain, the entire journey of a food item can be accurately documented and verified, starting from its origin to its destination. This level of transparency not only aids in preventing fraud and reducing counterfeiting but also empowers consumers to make informed decisions about the products they purchase. Furthermore, blockchain technology can bolster trust in the food supply chain by ensuring that claims regarding product quality and authenticity are backed by verified data.

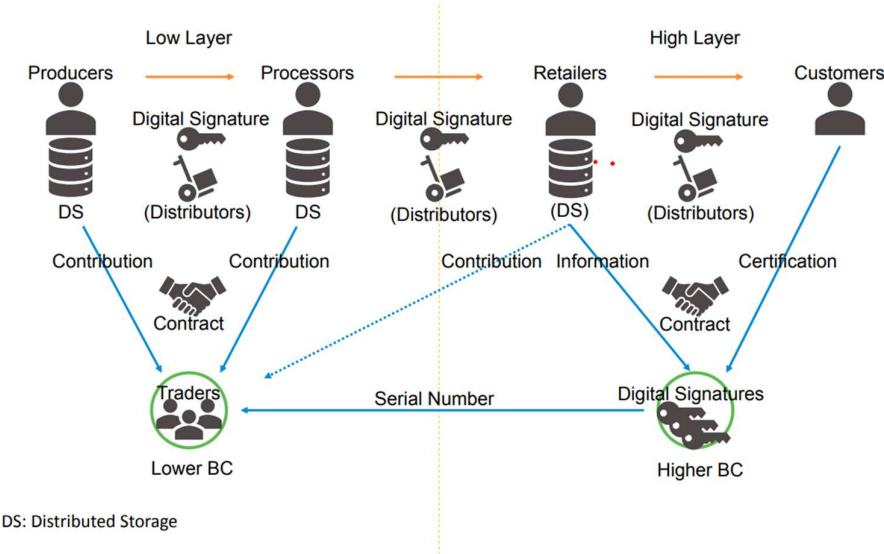


Figure 3. Source: (Kawaguchi, 2019).

Additionally, by integrating blockchain with other technologies such as IoT devices, the traceability and management of agri-food products can be greatly enhanced. Traceability plays a vital role in ensuring the management of food quality and safety. (Zhao et al., 2020) Traditional traceability systems in the food supply chain often lack in providing complete and transparent information to consumers. Blockchain technology has the potential to address these shortcomings by offering a decentralized and transparent system for recording and tracking food products.

Table 1. Source :[\(Tanwar et al., 2022\)](#).

Table 6. A comparative analysis of the existing approaches for food traceability.									
Author	Year	Description	Benefits	1	2	3	4	5	
Conti et al. [63]	2022	Olive oil traceability using cost-effective communication	The proposed system is easy to use and inexpensive	-	No	No	Yes	EVO-NFC	
Ling et al. [62]	2021	Blockchain- and AI-based food traceability system	Integrated system enhances the traceability, security, and monitoring of the food supply chain	Public	No	Yes	Yes	-	
Mirabelli et al. [64]	2020	Blockchain and agricultural supply chain traceability	The paper shows the benefits of BT as it is reliable and in its early stage; efforts are required to reach the maturation stage	Public	No	Yes	Y	-	
Salah et al. [48]	2019	A soybean traceability system using blockchain in agricultural supply chain	Ethereum blockchain and smart contracts used for soybean tracking and traceability	Public	Yes	Yes	Yes	Ethereum	
Baralla et al. [65]	2019	A European food supply chain system to ensure traceability using BT	This model shows the traceability from farm to fork in the European Union	Public	No	Yes	Yes	-	
Caro et al. [14]	2018	A practical implementation of food traceability based on blockchain in food industry	The proposed traceability solution for the supply chain system ensures seamless integration of IoT devices, which consume and produce digital data along with the blockchain data	Public	Yes	Yes	Yes	Ethereum	

1: Blockchain type, 2: authenticity, 3: data security, 4: support traceability, 5: framework used.

Traceability in Agriculture: The Role of Blockchain

Blockchain technology has the potential to revolutionize the traceability of food supply chains, ensuring transparency and accountability throughout the entire process. [\(Salah et al., 2019\)](#) By utilizing blockchain technology, every step in the supply chain, from farm to fork, can be documented and verified, granting consumers access to comprehensive information regarding the origin and quality of their food.[\(Demestichas & Daskalakis, 2020\)](#)This innovative technology not only has the capability to enhance food safety but also to promote sustainable practices by enabling the monitoring of crucial sustainability metrics such as carbon footprint and water usage. [\(Guido et al., 2020; Mirabelli & Solina, 2020\)](#) By harnessing the power of blockchain technology, the agricultural industry can effectively address concerns pertaining to food traceability and sustainability. This encompasses reducing food waste, enhancing supply chain efficiency, and advocating for fair trade practices .[\(Kouhizadeh & Sarkis, 2018\)](#) Through the implementation of blockchain technology in agriculture, we can establish a more sustainable and transparent food supply chain, fostering ethical practices and minimizing waste. [\(Liu et al., 2018; Wang et al., 2019\)](#) Furthermore, blockchain technology empowers consumers to make informed decisions about the food they purchase, enabling them to support sustainable farming practices and contribute to a greener future. Overall, the utilization of blockchain technology in agriculture holds immense potential to significantly impact supply chain sustainability and promote a more transparent and ethical food system. [\(Kouhizadeh & Sarkis, 2018\)](#) By leveraging blockchain technology, the agricultural industry can effectively address concerns related to food traceability and sustainability, ultimately establishing a more sustainable and transparent food supply chain.

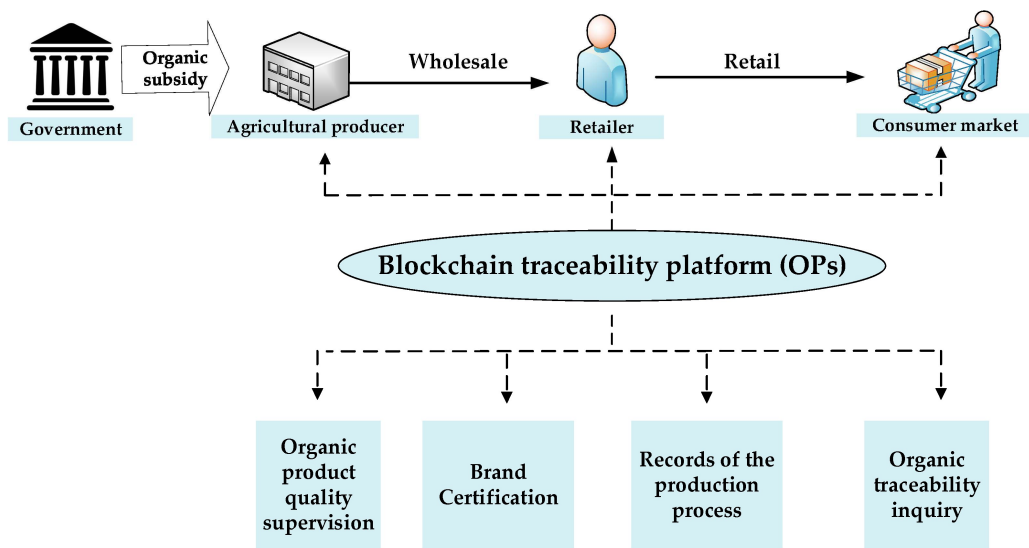


Figure 4. (Li et al., 2023).

The Impact of Blockchain on Farm-to-Fork Transparency

Consumers are expressing growing concerns about the origins and production practices of their food, seeking information on its source, cultivation or raising methods, and adherence to ethical and sustainability standards. This rising interest in food transparency has created a demand for increased information and accountability across the entire supply chain. Blockchain technology emerges as a viable solution to address these concerns, providing a decentralized and immutable ledger that meticulously records every transaction and movement of food from farm to table (Demestichas et al., 2020; Rejeb et al., 2020). By leveraging blockchain, a transparent and traceable system is established, enabling consumers to easily access comprehensive information about their food's journey. Through blockchain technology, consumers gain access to detailed insights about the farm of origin, production methods employed, and the certifications obtained. This heightened transparency empowers consumers to make informed choices, supporting sustainable and ethical practices.

Furthermore, blockchain proves effective in preventing fraud and reducing the risk of counterfeit goods infiltrating the food supply chain. With a transparent and traceable system, the introduction of fraudulent or counterfeit products becomes considerably more challenging. This not only safeguards consumers but also ensures fair compensation for farmers and producers. Beyond enhancing transparency and accountability, blockchain technology streamlines and automates processes within the agricultural industry. Farmers can utilize blockchain to monitor their crops from planting to harvesting, ensuring compliance with quality standards and minimizing waste. (Chandan et al., 2023) Additionally, this technology optimizes logistics and supply chain management, leading to increased efficiency and cost reduction.

In summary, the incorporation of blockchain technology in the food supply chain has the potential to significantly elevate transparency, accountability, and efficiency. It empowers consumers to make informed choices, advocates for sustainable and ethical practices, and guards against fraud and counterfeit goods. The agricultural sector has already made notable strides in integrating blockchain technology, and its continued adoption promises further enhancements in the farm-to-fork supply chain. (Khan et al., 2022)

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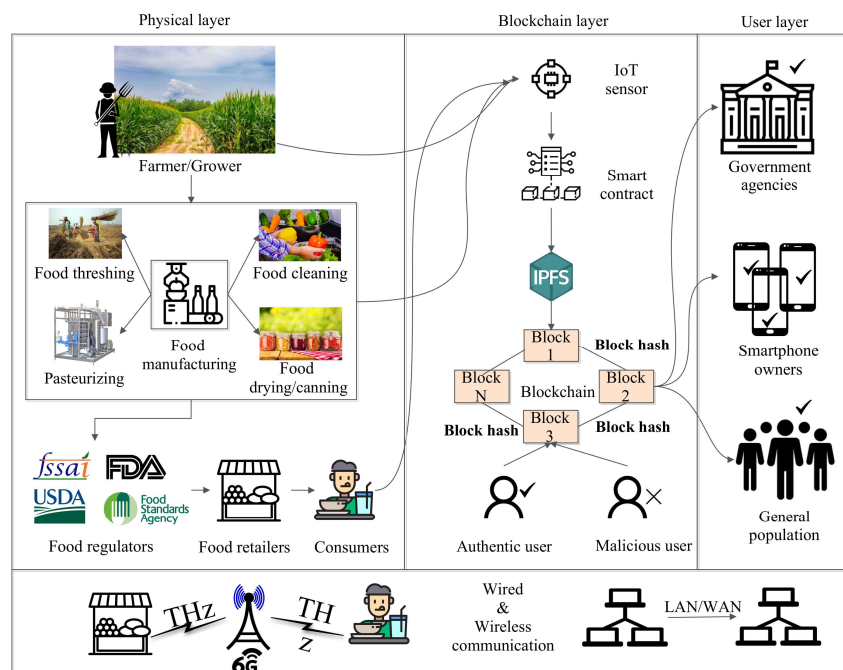


Figure 5. Source : (Tanwar et al., 2022).

Revolutionizing Food Safety with Blockchain Solutions

Blockchain technology has the capacity to revolutionize the assurance of food safety by transforming the way we monitor the entire food production process. Through the integration of blockchain and Internet of Things (IoT) technologies, a dependable and effective system for tracking and monitoring food production can be established. (Chang et al., 2019) This system engages all participants in the agricultural ecosystem, ensuring transparency and accountability throughout the food supply chain.

The utilization of IoT devices, in place of manual recording and verification, reduces human intervention and enhances efficiency. (Lin et al., 2022; Makhdoom et al., 2019) Furthermore, the incorporation of smart contract technology allows for prompt identification and resolution of issues. The adoption of a traceability system based on blockchain presents several advantages, including enhanced security, decentralization, immutability, and the ability to create smart contracts. These benefits address challenges linked to conventional centralized server-client systems, where consumers face difficulties accessing comprehensive transaction information and tracing product origins. (Sharma et al., 2023) The introduction of blockchain technology into the food supply chain facilitates sustainable food management and traceability. (Lin et al., 2022) (Srivastava et al., 2022) In summary, blockchain technology offers an innovative solution to enhance food traceability and safety. (Rejeb et al., 2019) Implementing a reliable food traceability system based on blockchain and IoT technologies has the potential to transform food safety by ensuring transparency, accountability, and efficiency throughout the entire food supply chain. (Rejeb et al., 2019) The incorporation of blockchain technology into the food supply chain can establish a trusted and effective system to monitor the entire life-cycle of food production, guaranteeing transparency and traceability. (Duan et al., 2020; Mohsin et al., 2019) Overall, blockchain technology holds the potential to revolutionize food safety and traceability by providing a dependable and efficient system for monitoring the entire food production process.

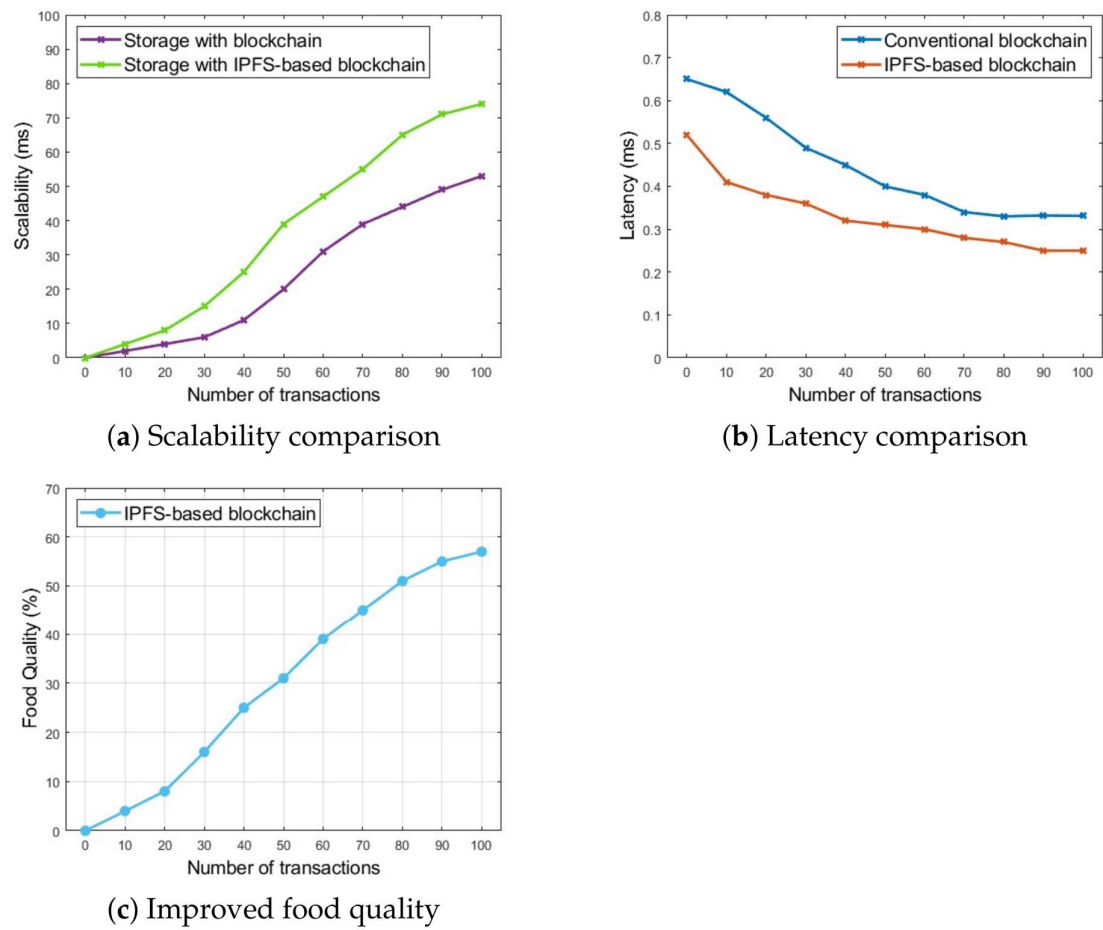


Figure 6. Source :[\(Tanwar et al., 2022\)](#).

Blockchain Applications: Streamlining Agricultural Operations

Furthermore, the paper delves into case studies and real-world examples of how blockchain technology has been successfully implemented in agricultural operations, such as supply chain management, food traceability, and quality control.[\(Ellahi et al., 2023\)](#) . It highlights the benefits of using blockchain in agriculture, such as increased transparency, efficiency, and trust among stakeholders. The paper also discusses the potential impact of blockchain technology on smallholder farmers and developing countries, emphasizing the importance of inclusive and sustainable agricultural practices.

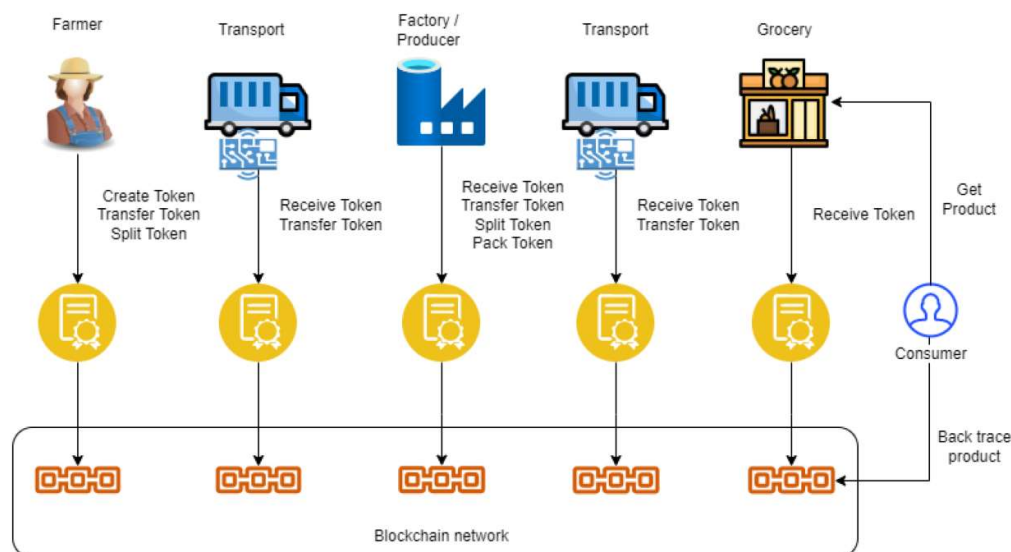


Figure 7. Source: (Tsoukas et al., 2022).

Overall, the paper serves as a valuable resource for researchers, policymakers, and industry professionals interested in exploring the potential of blockchain technology in agriculture. (Duan et al., 2020) A content-analysis based literature review in blockchain adoption within food supply chain. International journal of environmental research and public health, 17(5), 1784. It provides a comprehensive overview of the current landscape, challenges, and opportunities in this rapidly evolving field, offering insights into how blockchain can revolutionize agricultural operations and contribute to a more sustainable and transparent food system (Sugandh et al., 2023)

Building Trust in Food Sources with Blockchain Technology

Building Trust in Food Sources with Blockchain Technology In recent times, consumers have become increasingly concerned about the safety and quality of the food they consume. This growing concern has resulted in a heightened demand for transparency and traceability in the food supply chain. (Choi et al., 2020; Feng et al., 2019) While traditional traceability systems in the Internet of Things have offered some solutions, they often rely on centralized servers, which makes it challenging for consumers to access all the necessary information regarding the origin and journey of their food products. (Ding et al., 2023) However, blockchain technology presents a promising solution to this problem. By leveraging blockchain technology, the food supply chain can be transformed into a transparent and secure system, where all transactions and events are recorded in a decentralized manner. This ensures that the information remains tamper-proof and accessible to all participants. Consequently, consumers can easily track the origins of their food and verify its authenticity, thereby fostering trust in the food sources. Moreover, the utilization of blockchain technology in the food supply chain can effectively address other challenges such as food fraud and counterfeit products. By providing an immutable and transparent record of every transaction, blockchain technology significantly reduces the risk of fraudulent or counterfeit products entering the market. Additionally, it can enhance efficiency and reduce costs in the food supply chain by eliminating the need for manual record-keeping and third-party intermediaries. Overall, blockchain technology has the potential to revolutionize the food supply chain by enhancing traceability, transparency, and trust among consumers. (Cao et al., 2021) The introduction of blockchain technology brings tremendous potential to revolutionize the approach to food safety and traceability (Liu et al., 2018; Yadav & Singh, 2019). Through the utilization of blockchain technology, stakeholders in the food industry can establish a decentralized and transparent system that ensures the safety and quality of food products.

The Future of Agriculture: Blockchain-Enabled Supply Chains

Walmart Food Traceability in China: Walmart collaborated with IBM, Tsinghua University, and food suppliers to create a blockchain-based tracking system for pork and mangoes using Hyperledger Fabric blockchain. This system recorded product data, including farm source, batch numbers, processing details, expiration dates, and shipping information. The result was a significant reduction in tracing time, from days to just 2.2 seconds.

Agri Digital Grain Supply Chains: Agri Digital offers a cloud-based system where farmers input grain deliveries and quality data, linked to digital wallets and contracts on a blockchain. This not only ensures transparency but also automates transactions between farmers and commercial buyers.

Beef ledger Cattle Tracking: Beef ledger employs blockchain to record animal movements, health data, and slaughter details, providing a reliable monitoring system for the beef supply chain from farm to retailer. This enhances safety measures and prevents counterfeit meat trading.([Xu et al., 2019](#))

Fishery Transparency with Provenance: Provenance utilizes blockchain-enabled tagging for fresh tuna, tracing product attributes such as catch location, vessel, storage temperature, and processing facility. This ensures the verification of sustainability and food safety claims.([Probst, 2020](#))

HerdX Cattle Health and Location Monitoring: HerdX utilizes RFID tags, biosensors, and a blockchain ledger to deliver cattle health, genealogy, location, and environmental data to partners in the beef supply chain. This contributes to the prevention of animal diseases and ensures compliance.([Sharma & Koundal, 2018](#))

Ripe.io Food Safety for Fresh Produce: Ripe.io collaborates with farms, distributors, and grocers to record sensor, testing, and handling data for fresh produce shipments on the blockchain. This provides credible safety attestations to retailers and consumers.([Collart & Canales, 2022](#))

TE-FOOD Livestock Registration in Vietnam: TE-FOOD has successfully registered and tracked millions of chickens and livestock on a blockchain ledger throughout the supply chain in Vietnam. Unique identifiers enable continuous monitoring for quality control and food safety .([Vu & Trinh, 2021](#))

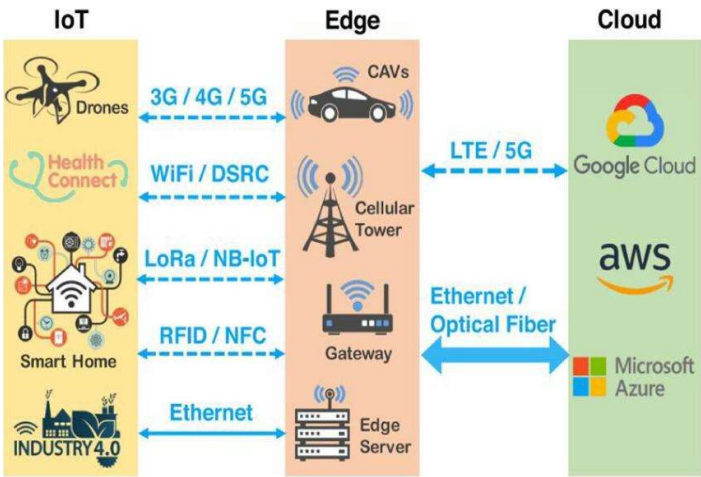


Figure 8. Source ;([Shi et al., 2019](#)).

Overcoming Challenges in Agricultural Traceability with Blockchain

Overcoming Challenges in Agricultural Traceability with Blockchain
Agricultural traceability involves tracking food products from farm to consumer. Implementing blockchain technology can address challenges and improve traceability. Here are ways blockchain can help:

Transparency and Accountability

Blockchain provides a transparent ledger for all supply chain transactions, fostering accountability and traceability.

Data Integrity

Blockchain ensures data integrity through cryptographic algorithms, preventing tampering and ensuring reliable traceability information.(Francisco & Swanson, 2018)

Decentralization

Blockchain provides a transparent ledger for all supply chain transactions, fostering accountability and traceability.(Hasanova et al., 2019)

Real-time Visibility

Blockchain enables real-time updates and visibility across the supply chain, allowing swift responses to issues like contamination outbreaks.

Smart Contracts:

Blockchain streamlines contract processes, reducing manual errors and improving efficiency.(Omar et al., 2021)

Conclusions

The integration of blockchain technology in agriculture significantly enhances transparency and traceability within the food supply chain, addressing consumer concerns regarding food safety, quality, and origin. By providing a secure and immutable record of transactions, blockchain fosters trust among stakeholders and promotes sustainable practices throughout the agricultural sector.

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