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BLOCKCHAIN IN FOOD SUPPLY CHAINS: A SURVEY OF THE LITERATURE AND SYNTHESIS OF PLATFORMS, ADVANTAGES, AND DIFFICULTIES

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Abstract-
The food supply chain now has a more complicated environment for enhancing efficiency and resolving issues as a result of the globalization of the food sector. Blockchain technology provides a viable decentralized alternative that can shorten transaction times and costs, boost efficiency and security, and foster participant confidence. The key blockchain systems currently utilized in the food supply chain are summarized in this research report. Explore the advantages and difficulties of blockchain technology in the food business by doing a thorough examination. Our findings demonstrate that blockchain technology delivers supply chain transparency at every stage never before possible. Supply of food, improving transaction transparency, ensuring the safety and quality of the food, and lowering fraud and food waste.
Keywords- Globalization, food industry, complexity, blockchain technology, efficiency, transparency, trust.

INTRODUCTION

Consumers have grown accustomed to getting food from all over the world, regardless of the season, as a result of the globalization of food supply chains in recent decades. You may get a straightforward illustration of this by ordering chocolate mousse with kalua at a café. Mexican Kalua, Swiss chocolate, Colombian coffee, Madagascar vanilla, Canadian crème fraîche, and cinnamon are among the ingredients. To make a meal, ingredients from India and eggs from nearby farms must travel hundreds of kilometers and pass through several hands. This picture Demonstrates how intricate the modern food economy is.

The food sector is becoming more globalized, there are more participants, perishable goods are being transported more slowly, and there is a growing knowledge gap in the food supply chain. As a result, food supply chain concerns are getting increasingly complicated and challenging to address in food systems. The complexity of each stage of the food supply chain is linked to problems including food waste, food safety, and financial hazards. According to research, ineffective food delivery networks result in the loss or waste of up to 30% of the food produced globally (Porter and Reay Citation 2016). A lack of openness and unethical behavior are to blame for serious problems like food fraud and recalls. Nowadays, there is a lot of food fraud. For instance, the use of artificial coloring and flavoring transformed low-cost oils into high-end olive oils. 10% of food sold worldwide, according to the Food Manufacturers Association, is tainted, costing consumers $49 billion year (Babich and Hilary Citation, 2020). Food recalls

further erode consumer trust and raise supply chain costs while undermining market share and trust among supply chain participants (Chen et al. Citation 2017). Food recalls, according to the US Grocery Manufacturers Association, have a large financial impact, with 23% and 52% of recalls totaling $3 million or more, respectively (Fisher Citation 2015). Customers have also expressed a want to track items, verify transactions, and comprehend how their food supply chains affect the environment. In the food supply chain, accountability, transparency, and social responsibility are more crucial than ever. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial for the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). Customers have also expressed a want to track items, verify transactions, and comprehend how their food supply chains affect the environment. In the food supply chain, accountability, transparency, and social responsibility are more crucial than ever. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial for the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). Customers have also expressed a want to track items, verify transactions, and comprehend how their food supply chains affect the environment. In the food supply chain, accountability, transparency, and social responsibility are more crucial than ever. Customers have shown a desire to track products, authenticate purchases, and comprehend the environmental impact of their food supply chains; this desire is known as "enterprise integration" and is crucial in the food supply chain. Electronic data transmitted over the Internet between business partners and value-added service providers is known as "enterprise integration," and it is essential in the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). In the food supply chain, accountability, transparency, and social responsibility are more crucial than ever. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial to the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). Customers have shown that they want to track items, verify transactions, and comprehend how their food supply chains affect the environment. In the food supply chain, accountability, transparency, and social responsibility are more crucial than ever. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial to the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). Accountability is more crucial than ever in the food supply chain. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial to the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017). Accountability is more crucial than ever in the food supply chain. "Enterprise integration" refers to the electronic data transmission through the Internet between business partners and suppliers of value-added services, and it is crucial to the food supply chain (Korpela, Hallikas, and Dahlberg Citation 2017).

Due to its openness, traceability, and security against unwanted access, a new decentralized information technology known as blockchain can be utilized to resolve issues and enhance commercial relationships in the food supply chain. authorized. A blockchain is a collection of blocks of data that constitute a distributed shared ledger shared across a number of trading networks (Hastig and Sodhi Citation 2020). If one block changes, the network collapses

because it can no longer connect to other blocks. The blockchain's immutable shared ledger makes it reliable, secure, and difficult to hack (Iansiti and Lakhani Citation 2017). It is safer and cheaper to store and sell physical and digital assets on blockchain networks. There are many problems in the food supply chain, from food safety to operational efficiency, and thanks to blockchain, we have found effective solutions. Reducing the importance of intermediate servers is another viable option as they are prone to failure, fraud and hacking (Tapscott and Tapscott Citation 2017). As a result, blockchain technology can increase supply chain efficiency and transparency, positively impacting everything from payments to shipping and warehousing (Azzi, Chamoun, Sokhn Citation 2019; Pournader et al. Citation 2020). and Sohn Quote 2019. Purnader et al (cited from 2020). and Sohn Citation 2019. Purnader et al (cited from 2020). as they are prone to failure, fraud and hacking (Tapscott and Tapscott Citation 2017). As a result, blockchain technology can increase supply chain efficiency and transparency, positively impacting everything from payments to shipping and warehousing (Azzi, Chamoun, Sokhn Citation 2019; Pournader et al. Citation 2020). and Sohn Citation 2019. Purnader et al (cited from 2020). and Sohn Citation 2019. Purnader et al (cited from 2020). as they are prone to failure, fraud, and hacking (Tapscott and Tapscott Citation 2017). As a result, blockchain technology can increase supply chain efficiency and transparency, positively impacting everything from payments to shipping and warehousing (Azzi, Chamoun, Sokhna Citation 2019; Pournader et al. Citation 2020). and Sohn Citation 2019. Purnader et al (cited from 2020). and Sohn Citation 2019. Purnader et al (cited from 2020).

Farmers, manufacturers, food processors, distributors, retailers and consumers are all involved in the food supply chain from start to finish. Agricultural suppliers (manufacturers of equipment, fertilizers, pesticides, etc.) are the first link in the network. According to Camilaris, Fonts, and Prenafeta-Bold (Quote 2019), each link in the food chain needs a unique set of data, all of which may be stored on the blockchain.

- Director: Information in-depth on the farm and the farming techniques employed, including crop techniques, climate, and livestock.
- CPU: Detailed information on production facilities and their equipment, processing technologies used, batch numbers, and financial transactions with manufacturers and distributors.
- Sales Agent: Delivery information, transit routes, storage conditions (such as temperature and humidity), travel time at each stage of the transportation process, etc.
- Retail Company: Complete information on each food, including current quality and quantity, best before date, storage requirements, and best before date.
- Consumer: Finally, consumers can use any mobile device or web application to scan a food's QR code and view all product details, from manufacturer to retailer.

In fig. 1 shows a digitized farm using blockchain technology. This underscores that on a blockchain platform, all food supply chain transactional data will become an immutable common ledger. Therefore, supply chain information available to authorized supply chain participants is transparent, reliable, secure, and tamper-proof.

The usage of blockchain in the food supply chain is examined in this article along with its current condition, prospective advantages for the food industry, and potential drawbacks. We're searching for answers to questions like:

- How might the blockchain's features assist solve issues with the present food supply system and enhance the food supply chain?
- What difficulties exist in using blockchain in the food supply chain?

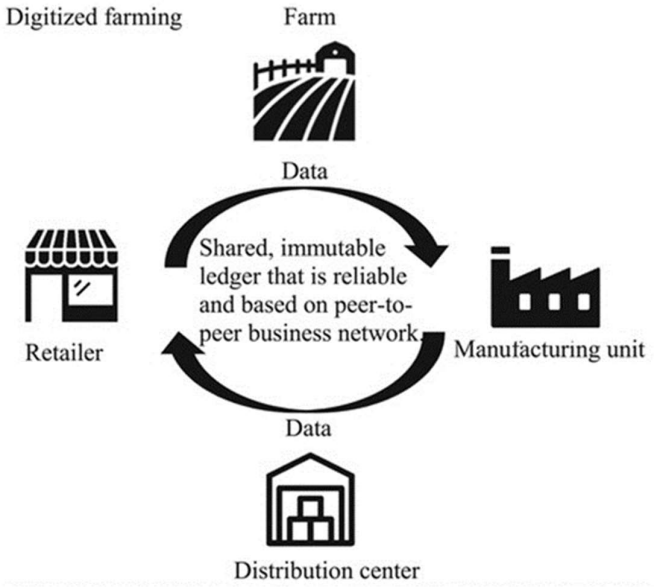

Figure 1. Blockchain in the food supply chain.

The remainder of the essay is organized as shown below. We will perform a thorough literature research on the application of blockchain in the food supply chain in Section 2. The existing blockchain-based systems in the food supply chain are introduced in Section 3. Part 4 examines how blockchain might enhance food quality and safety, supply chain resilience and efficiency. We also discuss the challenges associated with integrating blockchain into the food supply chain. Section 5 lists our findings.

Literature Review

We carried out a thorough analysis of the literature to determine the advantages and difficulties of using blockchain in the food supply chain, as well as which blockchain-based platforms are being discussed in the paddy field and food industry literature. We used Mayring's content analysis technique to perform a review of the literature (Citation 2004). According to Shukla and Jharkharia (2013) and Narayanamurthy and Gurumurthy (2016), this process, which consists of four parts, is frequently utilized for literature reviews. The following steps: (1) Compile the supplies. (2) a descriptive analysis; and (3) the choice of categories. (4) Material evaluation. In fig.

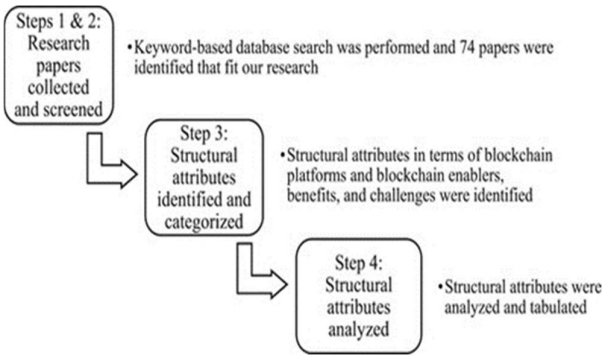

Fig. 2 shows the steps of the literature review.

Step 1: Collect Materials

For peer-reviewed journal papers published by May 2021 on blockchain, this stage entails scanning five research databases (Web of Science, Business Source Premier, ScienceDirect, Academic Search Premier, and ProQuest). supply of food. Food OR agriculture AND (blockchain OR blockchain OR distributed ledger) are the keywords in the title. The phrases "food" and "blockchain OR blockchain OR distributed ledger" were used in the abstract of a specific Google Scholar search as well. We were left with 74 pieces of evidence after excluding papers that refuted our findings.

Step 2 - Descriptive analysis

We gathered and examined information on publishing years and distributors to understand future directions for this field of study. Table A1 in the appendix contains a list of the 74 peer-reviewed papers' published years. This suggests that blockchain research in the food supply chain is a new and expanding area of study. Table A2 in the appendix provides a summary of the journal information for the questioned article. The table displays the 46 publications that have published studies on the use of blockchain in food supply chains. The International Journal of Production Research, Sustainability, IEEE Access, and Journal of Cleaner Production are some of the most well-known research websites.

Step 3: Choose a category

We have recognized and categorized the structural characteristics of this stage in terms of blockchain-based platforms, blockchain implementation tools, advantages, and problems for future research and debate.

Our study focuses on blockchain-based systems that link users (farmers, food producers, merchants, restaurants, distributors, consumers, etc.) and assure information sharing and positive user interactions for business or management. Please be aware that the main goal of our study is not to design and execute computer applications on platforms (like VeChain and Ripple).

The advantages of blockchain technology in the food supply chain are divided into two groups: opportunities and advantages. While enablers are the first-tier advantages that result directly from blockchain capabilities, perks are the second-tier benefits that derive from enablers. For instance, food safety is improved (benefits) via blockchain traceability and transparency (two contributing variables). The many forms of obstacles to the adoption and use of blockchain have also been classified. Table 1 outlines the blockchain classifications, benefits, and drawbacks that we discovered.

Traceable data structures, record immutability (records cannot be changed), consensus mechanism (all records are updated by a consensus process among participants), and smart contracts (automatically carried out by the software) are all features of the blockchain. It is a distributed database with features like functions in accordance with the contract's requirements). The following are the immediate advantages of various blockchain enablers:

- Transparency: Due to everyone's access to a distributed database, all supply chain data is available to participants.
- Traceability: Using traceable data structures, blockchain enables quick tracking of several steps in the supply chain, both upstream (the origin of the food and its history of processing and distribution) and downstream (where it is sold/used).

- Due to its immutability, blockchain ensures both security against unwanted access to data and the authenticity of components.
- Data Security: Data cannot be tampered with or changed by attackers because to blockchain's distributed database, consensus mechanism, and encryption features.
- Automated transactions: Automated transactions such as automatic payments and replenishment are made possible by blockchain smart contract technology.

For the food supply chain, these incentives provide many secondary benefits that can be grouped into the following categories.

- Food quality and safety. Food traceability can improve food quality and safety through transparency and traceability.
- Decreased transaction times and costs: Automated transactions (automatic peer payments, decreased delays due to the elimination of paperwork, etc.) and the elimination of different procedures may both cut transaction times and costs for supply chain activities. Intermediaries in the supply chain for food.
- Greater income. Increasing customer trust in the provenance and quality of our products can result in increased sales and pricing, which can increase income.
- Boost supply chain effectiveness: Supply chain efficiency may be increased by removing intermediaries (such direct trades between farmers and merchants), better matching supply and demand, and spotting improvement possibilities through real-time data sharing on the blockchain. to boost efficiency.
- Promote sustainability: By minimizing food waste, conserving resources, tracking carbon footprints, and promoting fair trade along the food supply chain, blockchain works to promote sustainability.

Many difficulties related to the adoption and uses of blockchain have been explored in the literature. We have divided them into five groups and presented them in Table 1. The instances that fall into each category are shown below.

- Technology: compatibility and standardization, lack of knowledge and skills, scalability.
- Governance: data ownership, ethical standards, and privacy issues.
- Regulation: Poor government regulation and unpredictable regularity.
- Cost: The resources (energy and infrastructure needed to run a blockchain) and the initial capital required is the cost.
- Lack of knowledge and education is exemplified by a lack of stakeholder trust, a lack of stakeholder user experience and comprehension, and hostility to the blockchain culture.

Table 1. Opportunities, advantages, and challenges of blockchain

activator	advantage	Subject
E1. Transparency	B1. Food sanity and excellence	C1 technology
E2. Traceability	B2. Decreased transaction costs and duration	C2. Control
E3. Reliability	B3. Revenue increase	C3. Rules

E4. Data security	B4. Improve supply chain efficiency	C4. Costs
E5 Auto Trade	B5. Promote sustainable development	C5. Awareness and education

Step 4: Hardware assessment

We evaluated and reviewed articles detailing the structural features found in Phase 3 of this phase. Documents that fell outside the scope of the review, such as blockchain system design documents, were excluded. The results of the review are summarized in Table 2 and serve as the basis for the synthetic analyzes in Sections 3 and 4.

Table 2 summarizes the results of the evaluation.

paper	research method	activator	advantage	Subject
Ali and others (quote 2021)	KS, IV	✓	✓	✓
Astil and others (quote 2019)	South Africa	✓	✓	
Chen et al. (cited in 2020)	South Africa			
Duanne et al. (cited from 2020)	South Africa	✓	✓	✓
Galvez, Mejuto, Simargandhara (Quote 2018)	South Africa	✓	✓	✓
Kohler and Pizzol (Quote 2020)	KS	✓	✓	✓
Kumar, Liu, Shang (Quote 2020)	KS		✓	
Nurgazina and others (cited 2021)	single lens reflex camera	✓	✓	✓
Pearson et al. (quote 2019)	South Africa	✓	✓	✓

NOTE. “CS” stands for a case study, “IV” stands for an interview, “SA” stands for survey analysis, “SLR” stands for systematic literature review, “SV” stands for statistical review, “SLR, CS” In this study, the two SLR and CS methods were used.

Blockchain-based platform for the
Agriculture and food industry

In order to increase the efficiency of food production, storage, processing, distribution, and availability, food supply chains have begun to use online platforms since the advent of information and communication technology and e-commerce solutions. Figure 3 from Citation 2017 depicts an illustration of a platform (both blockchain-based and non-blockchain) that makes it easier to move commodities, services, and information from farm to farm and vice versa, in accordance with Gharehgozli et al. These platforms may be divided into four basic categories: food processing and distribution, food delivery, food delivery, and food production and distribution. exchange of trash. First-rate platforms serve as the representation for nearly all of the participants in the upstream and downstream food chains. On the other hand, other

platforms are more specialized and intended to increase consumer access to food. There are also two platforms for ordering and delivering meals. Pizzerias, restaurants, and supermarkets frequently employ direct-to-consumer (or restaurant) delivery as the initial option. The other is platform-to-consumer delivery, which serves as a middleman for on-demand food and grocery delivery between clients, eateries, and marketplaces. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). First-rate platforms serve as the representation for nearly all of the participants in the upstream and downstream food chains. On the other hand, certain platforms fall under more specific categories that are intended to increase consumer access to food. There are also two platforms for ordering and delivering meals. One is the customer (or restaurant); pizzerias, restaurants, and supermarkets frequently use it for home delivery. The other is platform delivery to the consumer, which serves as a middleman for the on-demand delivery of food and grocery items between customers, eateries, and supermarkets. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). First-rate platforms serve as the representation for nearly all of the participants in the upstream and downstream food chains. Other types of platforms, on the other hand, are more specialized and intended to increase consumer access to food. Additionally, there are two systems for ordering and delivering food. Pizzerias, restaurants, and supermarkets frequently employ direct-to-consumer (or restaurant) delivery as the initial option. The other is the platform's delivery to the customer, which serves as a middleman for the on-demand delivery of food and goods between customers, restaurants, and supermarkets. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). On the other hand, it is more focused and tries to increase consumer access to food. There are also two platforms for ordering and delivering meals. Pizzerias, restaurants, and supermarkets frequently employ direct-to-consumer (or restaurant) delivery as the initial option. The second method is platform-to-consumer delivery, which serves as a middleman between customers, restaurants, and supermarkets for the delivery of food and other on-demand goods. Food delivery services are expanding and were crucial in the COVID-19 epidemic (Hobbs Citation 2020). On the other hand, it is more focused and tries to increase consumer access to food. There are also two platforms for ordering and delivering meals. Pizzerias, restaurants, and supermarkets frequently employ direct-to-consumer (or restaurant) delivery as the initial option. Another option is platform-to-consumer delivery, which serves as a middleman between customers, restaurants, and supermarkets to deliver food and goods on demand. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). Restaurants, pizzerias, and grocery stores utilize it frequently. Another option is platform-to-consumer delivery, which serves as a middleman between customers, restaurants, and supermarkets to deliver food and goods on demand. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). Restaurants, pizzerias, and grocery stores utilize it frequently. The second method is platform delivery to the consumer, which serves as a middleman for the on-demand delivery of food and goods between customers, restaurants, and supermarkets. Platforms for food distribution are expanding and were crucial during the COVID-19 epidemic (Hobbs Citation 2020). The first is platform-to-consumer delivery, which serves as a go-between for customers, restaurants, and supermarkets to deliver food and groceries on demand. Platforms for food distribution are

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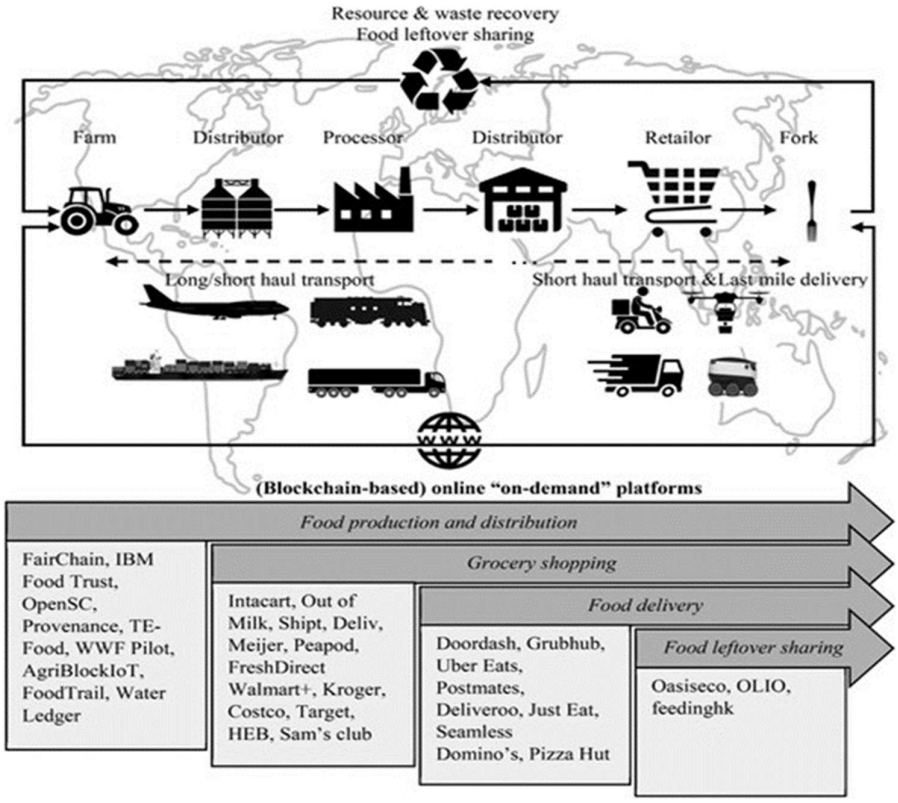

Figure 3. Global Food Supply Chain Platform

The food supply chain has concentrated on creating platforms based on blockchain for food production and farm-to-table elivery (Köhler and Pizzol Citation 2020). FairChain, IBM Food Trust, OpenSC, Provenance, TE-Food, World Wide Fund (WWF) Pilot, AgriBlockIoT, FoodTrail, and Water Ledger are a few examples of blockchain-based systems. Even though these platforms are still developing, they are already generating significant improvements to the food supply chain, including decreasing food waste and increasing the effectiveness of food production and transportation.

While other categories, including food delivery and surplus exchanges, are less often employed, blockchain can be used to provide a means for hedging supply chain risks linked with online platforms (quote 2019). Benefits include guaranteeing the quality of the food and meals, spotting erroneous or deceptive orders, confirming the identities of the customers and drivers, and lowering commissions.

The key performance indicators (KPIs) connected to the most widely used blockchain-based solutions in the food sector will next be covered. An overview of

each of the blockchain-based platforms we'll talk about may be found in Table 3. Please be aware that not all blockchain-based systems utilized in the food supply chain are included in this list. For instance, there are blockchain-based systems for specialized food sectors, such as OliviaCoin for olive oil, AgriDigital for grains, Grain Discovery for grains, BeefLedger and BeefChain for cattle, OriginTrail for poultry, and others (Schahczenski and Schahczenski Citation2020, Kamilaris, Fonts, and Prenafeta). - 2019 quotation, in bold).

Table 3. An explanation of well-known platforms based on blockchain for the food supply chain.

platform based on blockchain	Description of the researchers and developers	Recommendations
fair chain	“Fair Agriculture is the practice by which farmers and workers earn a living wage by operating profitable farms and engaging in value-added activities to improve their livelihoods and improve their communities.”	Fair Network (Citation2021)
IBM Food Trust	"A modular blockchain-based solution that benefits all network participants through a safer, smarter, and more sustainable food ecosystem."	IBM Food Trust (Citation 2021)
CS open	"OpenSC creates unprecedented opportunities to connect manufacturers at the beginning of the value chain to the end consumer. Additionally, the data collected by OpenSC will enable us to develop scientific fisheries management and supply chain operations. We can be at the forefront."	OpenSC (Link 2021)
history	"We enable leading brands to communicate the origins and impact of their products. We connect with changing consumer values to increase engagement and help build a better world."	Origin (Citation2021)
tee hood	"A blockchain-based farm-to-table food tracking solution designed to improve the reliability and efficiency of the food industry."	TE-Food (Quote 2021)
WWF Pilot	“The Blockchain Supply Chain Tracking Project traces fish from ship to supermarket using digital technology to improve supply chain management in the fresh and frozen tuna sector in the Western and Central Pacific ."	WWF (cited 2021)
Internet of Things Agroblock	“A fully decentralized blockchain-based tracking solution for agri-food supply chain management, seamlessly integrating IoT devices that produce and consume digital data across the entire chain.”	Karo and others (quote 2018)
food trail	"The FoodTrail blockchain will record and track the movement and processing of food through the supply chain"	Hayati and Nugraha (Quote 2018)
pound of water	"Waterbook is the world's first secure license-focused platform powered by blockchain technology that is changing the way water licenses are managed, ensuring sustainability and building trust."	Book of water (Citation2021)

Table 4 presents the key performance indicators for each blockchain-based platform. Data availability is a key KPI from a supply chain perspective. All transactions on public blockchains are visible to all users. Only authorized parties have access to transactions on a private blockchain. Provenance, OpenSC, WWF Pilot, AgriBlockIoT, FoodTrail and Water Ledger are built on public blockchains. TE-Food is built on a combination of public and private blockchains, while FairChain and IBM Food Trust are built on private blockchains. Even though public blockchain-based systems are more transparent and therefore more reliable,

private platforms need to be more adaptable and flexible to meet the needs of many actors in the food supply chain. Moreover,

Table 4. KPIs of blockchain-based platforms in the food supply chain

Blockchain-based platform	main product	private blockchain	public blockchain	Required knowledge	Software integration
fair chain	coffee, chocolate	✓	✓	offline data	-
IBM Food Trust	Food and drink	✓	✓	-	-
CS open	seafood	-	✓	✓	-
history	seafood	-	✓	ERP integration	-
tee hood	food	✓	✓	✓	offline data
WWF Pilot	seafood	-	✓	offline data	-
Internet of Things Agroblock	food	-	✓	Internet of Things (IoT) devices	-
food trail	food	-	✓	-	-
pound of water	water	-	✓	-	-

Note:

- ✓ indicates that the platform supports the corresponding feature.
- "-" means the function is not applicable or not specified.

The knowledge requirements of blockchain users and developers are another KPI that can influence the adoption of blockchain-based solutions. Almost every platform today requires a basic understanding of platform administration and programming. It can be difficult to train users to operate the system efficiently, particularly for farmers and fishers in poor nations. As a result, it becomes imperative to develop user-friendly platforms that support multiple data entry techniques (text messages, online logs, GPS coordinates, third-party records, etc.) and tracking technology systems (NFC tags, tags RFID, etc.) QR code, barcode).

The final important food supply chain KPI is the capacity of blockchain-based platforms to interface with multiple existing apps, platforms, and technologies. Just a few of the blockchain-based technologies that can save data offline are TE-Food, FairChain, and WWF Pilot. Regional enterprise resource planning (ERP) systems may be connected to by other platforms, such as Provenance. Problems may result from this and blockchain data security may be jeopardized. Blockchain data management requires the development of protocols and standards.

Blockchain's Potential and Drawbacks in the Food Supply Chain

This section will first go over how blockchain technology may assist address some of the most urgent issues in the food supply chain while also enhancing the quality and safety of food. The advantages of sustainability and how the food supply chain operates are then covered. Finally, we look at how challenging it is to adapt and use blockchain in the food supply chain.

Benefits of Blockchain in the Food Supply Chain for Food Safety and Quality

Due to a lack of openness in the food supply chain, the food sector confronts issues with food quality and safety. The transparency and traceability offered by blockchain technology can

enhance the quality and safety of food. Blockchain makes it possible for those involved in the food supply chain to track down product origins, reducing food waste and preventing food fraud. This technology also enables the rapid identification of contaminated foodstuffs, allowing for faster recall. Research shows that consumers want transparency about the foods they buy, from the full breakdown of ingredients to information about the supply. Blockchain capabilities can help meet this demand for transparency and increase brand loyalty. In general, blockchain can bring great benefits to businesses and consumers by improving food safety and quality.

Blockchain's operational advantages in the food supply chain

The elimination of rivalry and trust concerns that limit the use of vast volumes of data that are available to all parties is one of the operational benefits of blockchain in the food supply chain. These obstacles prevent the adoption of cutting-edge technologies like RFID, telematics, barcodes, sensor technology, and IoT to track food and gather supply chain performance data. By linking the whole supply chain digitally and producing a secure, shareable, and approved record of transactions, blockchain breaks down these boundaries. Additionally, blockchain improves the efficiency, security, and transparency of transactions.

Blockchain's advantages for food supply chains' Sustainability

By making it simpler to trace agricultural practices and commodity origins, blockchain can support sustainable agriculture and help customers make educated purchasing decisions. By introducing transparency and traceability to the supply chain, blockchain can also encourage sustainable practices in the farm-to-fork value chain. In the end, this may result in more sustainable and moral food systems that are advantageous to both society and the environment.

Food Supply Chain Blockchain Implementation Challenges

Although there is a lot of promise for blockchain technology to transform the food supply chain, there are still several obstacles in the way of its adoption. The main issues include:

- Integration with existing systems: Integrating a blockchain with existing systems such as ERP can be complex and difficult. This requires a significant investment of resources and time.
- Standardization: Lack of standardization regarding data formats, blockchain architecture, and interoperability between blockchains can be a barrier to adoption.
- Confidentiality and data security. Blockchain improves security but also raises data privacy concerns. Companies must ensure that there is no leakage of sensitive information when exchanging sensitive information on the blockchain.
- Acceptance by small and medium-sized enterprises (SMEs): Many SMEs lack the resources and technical expertise to implement blockchain, which makes it difficult for them to participate in blockchain-based supply chains.
- Regulatory issues: There currently needs to be standardized rules for blockchain-based supply chains. This can create legal uncertainty and delay implementation.
- High cost: Implementation and maintenance costs associated with blockchain technology can be high. This can be a barrier for some businesses, especially small businesses.

All parties involved in the food supply chain, including growers, manufacturers, distributors, and retailers, must work together to overcome these obstacles.

High implementation costs, a lack of industry standards and interoperability, a lack of technical expertise, difficulties integrating with current systems, data privacy concerns, security concerns, legal and regulatory issues, and other issues are obstacles to implementing blockchain in the food supply chain. Some stakeholders who have not yet fully grasped the advantages of blockchain technology can also be resistant. Despite these difficulties, several businesses and institutions continue to research how blockchain technology may enhance the quality, safety, and sustainability of food in their supply chains.

Conclusion and Discussion

This study provided the first presentation of the primary blockchain platforms currently being utilized in the food supply chain following a thorough analysis of the literature. Then, we carried out a thorough research to investigate the advantages and disadvantages of blockchain technology in the food supply chain. We examine the four major issues the food sector is facing—lack of traceability, food fraud, product recalls—as well as how blockchain technology might benefit the food supply chain in terms of food safety and quality. food supply and food safety. The commercial advantages of blockchain were then covered, including how to speed up transactions, boost revenue, and enhance supply chain effectiveness to enhance the operational effectiveness of food supply networks. Blockchain was also briefly touched upon. sustainability advantages. There are several obstacles to using blockchain in the food supply chain, including those related to technology, finances, governance, regulations, expertise, and education. sustainability advantages. There are several obstacles to using blockchain in the food supply chain, including those related to technology, finances, governance, regulations, expertise, and education. sustainability advantages. There are several obstacles to using blockchain in the food supply chain, including those related to technology, finances, governance, regulations, expertise, and education.

Blockchain technology is a cutting-edge platform that leverages open, transparent, and decentralized commercial processes in supply chains. We demonstrate how blockchain technology may improve food safety, transaction transparency, and waste reduction while reducing costs and delivering unmatched insights at every point in the food supply chain. It is a technology strategy to lower costs and boost productivity in the food supply chain. The food supply chain players become more trustworthy when all data, goods, and financial transactions are transparent, traceable, and immutable.

Although the focus of this essay is on the usage of blockchain in food supply networks, our conclusions are applicable to a wide range of supply chains. For instance, international trade (Yoon et al. Quote 2020), industrial supply networks (Karamchandani et al. Citation 2021), and humanitarian supply chains (Dubey et al. Citation 2020; Rodrguez-Espndola et al. Citation 2020). Our paper, among other things, (i) demonstrates how blockchain may be used to increase efficiency and (ii) records the movement of materials from suppliers to manufacturers and retailers to assist address customer concerns about product origin, safety, and quality. By sharing information and making supply chain operations transparent, you can increase supply chain efficiency. You can also (iii) cut down on lead times by digitizing paperwork and automating processing. Additionally, blockchain research and technology are still in their infancy. In-depth analysis, literature reviews, case studies, and academic research are the key techniques employed in the current study. Blockchain integration into analytical models will be a fascinating field of study. The advantages of blockchain have been given and addressed

in this paper in a qualitative manner. It would be excellent to incorporate quantitative research on blockchain technology's advantages from early users. Blockchain-based systems are in these domains, despite the fact that there are obvious advantages.

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