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Blockchain Technology: A Game Changer For Food Traceability And Security

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Abstract
Blockchain technology is transforming the food industry by offering creative approaches to persistent security and traceability issues. Immutability, improved visibility, openness, and data integrity all work together to build trust in extended food supply chains (FSCs) in several ways. Blockchain can help reduce the danger of counterfeit goods and other illegal trades, improve traceability, and facilitate more effective recall. Furthermore, by incorporating the claim's authoritative source (such as the certification body or certification owner) into the blockchain, blockchain can improve the integrity of credence claims like sustainably sourced, organic, or faith-based claims like kosher or halal. This will reassure end users and business clients. This systematic evaluation synthesizes data from ten (10) studies using a meta-analysis approach to assess the impact of blockchain. The systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol for data gathering, extraction and reporting. The study used Google Scholar, Science Direct and Web of Science databases to gather articles used in this study. In addition to lowering the risks of food fraud and contamination, key findings show notable gains in tracking, transparency, and regulatory compliance. The analysis also identifies obstacles and suggests ways to use blockchain technology in the food supply chain going forward.
Keywords: *Blockchain, food supply chain, Technology, Food traceability, Food security*

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I. Introduction

The global food supply chain is becoming intricate, and various stakeholders, such as farmers, processors, distributors, retailers and consumers, are involved (Djekic, et al., 2021). Due to this intricacy, there have been frequent difficulties in ensuring food safety, traceability, food quality, trustworthiness and inefficiencies within the supply chain (Chhetri, 2024; Malik, et al., 2024). A decentralized, transparent, and impenetrable ledger provided by blockchain technology has been suggested to solve these issues, potentially improving efficiency and confidence throughout the food supply chain. According to Feng et al. (2020), the food traceability system tracks food products from farm to consumer, ensuring quality control and safety throughout the entire Food Supply Chain (FSC). It provides the ability to trace products in both forward and backward directions when needed. As traceability becomes a key quality indicator, food authorities enforce regulations to monitor and identify raw materials used in food production. While many FSC participants have adopted traceability measures, some still rely on paper-based systems. Traditional record-keeping technologies address some of these challenges but do not resolve all issues. Traditional Food Supply Chains (FSCs) are marked by strong vertical integration and coordination among supply chain partners, which enhances efficiency by reducing transaction, operational, and marketing costs while meeting consumer demands for food quality and safety. As a result, FSC participants are facing growing pressure to increase supply chain transparency, improve the sharing of reliable information, and strengthen the traceability of agricultural products from farms to retailers. Therefore, advanced technologies like the Internet of Things (IoT) are being introduced to improve traceability. IoT applications provide real-time data on products and contamination during production and distribution. Additionally, blockchain technology, which is gaining popularity, offers a transparent, tamper-proof, and secure system for tracking food safety.

As the demand for food rises, so does the threat to food safety, requiring increased attention. The World Health Organization (WHO) emphasizes that ensuring food quality and safety remains a persistent challenge for both the food industry and scientific communities, with millions suffering each year from contaminated food (World Health Organization, 2015). Ensuring the production of quality food is a key aspect of food security, which involves systematic research to monitor existing quality regulations and standards across all stages, from production, through processing, and transportation, to the consumer's purchase. In developed nations, food safety is a major concern, as consumers demand higher quality and safer food products (Franz, et al., 2019). Blockchain's potential in the food sector is growing, with applications that improve traceability and build consumer trust by enabling efficient food tracking and crisis response. This technology can efficiently handle consumer inquiries about food products' safety, quality, and environmental sustainability (Ping, et al., 2018). It gives customers more freedom to communicate with food producers and gives them a better understanding of how food is made (Creydt & Fischer, 2019). Blockchain technology is advantageous from a regulatory standpoint because it helps authorities enforce legislation by providing trustworthy data. Because blockchain has many uses in food supply chain management, several businesses have already embraced it in agriculture (Johns, et al., 2024). For instance, blockchain-based traceability systems have been put in place by Wal-Mart, JD.com, and Alibaba to closely monitor every aspect of their food manufacturing, processing, and sales processes. Blockchain is a decentralized, digital ledger that records transactions without a trusted third party, allowing data to be processed, stored, and accessed securely. This study systematically explores how blockchain technology is changing food security and traceability.

II. Literature Review

Concept of blockchain technology (BCT)

A person or organization going by the pseudonym Satoshi Nakamoto first proposed the idea of Blockchain Technology (BCT) in 2008 (Patel, et al., 2023). It was created as a digital, decentralized public record for Bitcoin transactions. Nakamoto's system timestamps blocks using a technique inspired by hash cash, eliminating the need for dependable central authorities or interference from the conventional financial industry (Giungato, et al., 2017). Decentralization, immutability (making it a justified technology for industries like finance, healthcare, cybersecurity, food supply chain and public services), and consensus are the guiding concepts of blockchain technology (Radanovic & Likic, 2018). Important elements consist of a distributed ledger (guaranteeing that all parties can access data through digital records called blocks); smart contracts (enforce compliance and automate procedures); and data confidentiality and integrity are safeguarded by cryptographic security.

Framework of Food Traceability

In recent years, the idea of "traceability" has become increasingly popular in a variety of industries, including software development (Patelli & Mandrioli, 2020), the automotive sector (Sood, et al., 2022), and aerospace (Dasaklis, et al., 2022). Several researchers have developed frameworks and models to handle the increasing complexity of traceability in the food supply chain. Aung and Chang (2014) analysis of the food supply chain focused on the flow of information and products using a traceability framework (Figure 1). Their concept distinguishes between external traceability, which extends beyond supply chain partners, and internal traceability, which takes place within an organization, to achieve comprehensive "whole supply chain traceability." Their framework also incorporates quality assurance systems and regulations in addition to the essential elements of the food traceability information system. Similarly, Lindvall and Sandahl (1996) explored traceability in software development, categorizing it as vertical and horizontal traceability. Wognum et al. (2011) applied these terms in a broader context, describing vertical traceability as compliance with legislative requirements and horizontal traceability as the sharing of information between stakeholders. These interpretations illustrate diverse perspectives on traceability across industries.

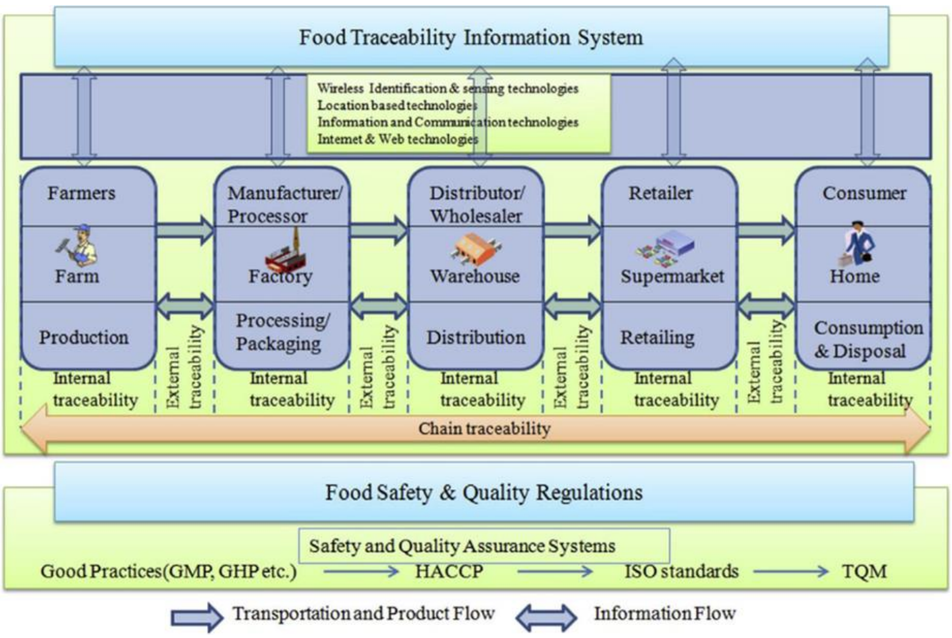

Figure 1: Framework of Food traceability

Concepts of Food Security

Despite being explicitly established in the 1970s, the idea of food security has origins in previous debates (FAO, 2012). The United Nations Conference on Food and Agriculture in 1943 underlined how crucial it is to guarantee each nation has a safe, sufficient, and suitable food supply (United Nations, 2021). Food security was defined as the continuous availability of enough basic food supplies to prevent acute shortages during crises and support steady growth in food consumption, especially in countries with low per capita intake. The term was formally recognized during the 1974 World Food Conference (United Nations, 1975). A global food crisis characterized by rising hunger and skyrocketing food costs gave rise to this description. The availability, use, accessibility, and stability of food resources are all aspects of the multifaceted concept of food security. To guarantee that populations consistently have access to enough safe, nourishing food to satisfy their dietary needs and preferences for an active and healthy life, a strong framework for food security includes several components (Figure 2). The first dimension is availability, which emphasizes the consistent production, storage, and supply of food to meet the population's needs (Béné, 2020). It ensures that agricultural systems, infrastructure, and supply chains operate efficiently. The second dimension, access, focuses on the ability of individuals to obtain sufficient food through economic means, markets, or social safety nets (Zhichkin, et al., 2021). This highlights the importance of affordability and equitable distribution systems. Utilization, the third dimension, addresses the effective use of food to meet nutritional and health needs, factoring in food safety, preparation methods, and access to healthcare (Pozza & Field, 2020). Finally, stability refers to the reliability and resilience of these dimensions over time, accounting for risks such as climate change, economic fluctuations, and political instability (Clapp, et al., 2022). Frameworks for food security integrate these dimensions to provide a holistic approach, enabling policymakers and stakeholders to design strategies that ensure sustainable and equitable food systems (Zsögön, et al., 2022).

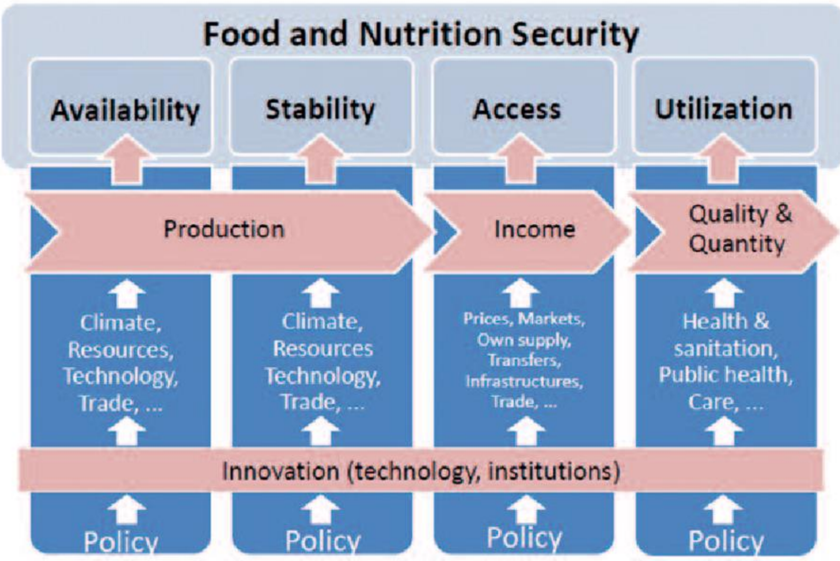

Figure 2: The Concept of Food Security
Source: (Braun, 2014)

Blockchain Technology in the Food Sector

Blockchain is defined as a distributed, decentralized, digital ledger that creates permanent, unchangeable records by recording transactions in chronological order (Treiblmaier, 2018). Rejeb et al. (2018) claim that blockchain integrates some tools, technologies, and approaches to solve certain business problems. According to Salah et al. (2019) blockchain, which was first connected to cryptocurrencies, has become popular in supply chains and logistics because it increases transparency, guarantees transaction immutability, and builds confidence amongst food players.

The necessity to address the intricacies and health risks of contemporary food systems is driving the ongoing development of blockchain technology integration into food supply chains (FSCs). For example, Dubai's "Food Watch" program uses internet and blockchain technology to enhance food safety, streamline procedures, and give customers access to nutritional data from more than 20,000 restaurants (Detwiler, 2018). Also, Chinese retailers Jindong and Kerchin have used blockchain to track meat items (IBM, 2023), giving buyers comprehensive information like breed, weight, diet, and farm locations via QR codes, while Walmart, International Business Machine Corporations (IBM), and Tsinghua University have utilized it to improve food safety and traceability in China (Kshetri, 2018).

III. Methodology

This review utilised the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol for data gathering, extraction and reporting. The study used Google Scholar, Science Direct and Web of Science databases to gather articles to be used. Keywords such as "blockchain technology," "food traceability," "food security," “decentralized ledger,” and "supply chain transparency." were used in a thorough database search. Boolean operators like AND, and OR were used to combine search terms when searching databases. Examples include; "blockchain technology and innovative technology," "food traceability of food tracking," "food security or food safety," and "supply chain transparency or supply chain authenticity." Peer-reviewed papers, conference proceedings, and case studies were published between 2015 and 2024 and met the inclusion requirements and were used for study discussion, the selection criteria are shown in Table 1. The initial search string produced 475 articles (database-460 and other sources-15). Based on the title and abstract, the search string provided 150 studies, after screening and eligibility evaluation, 45 of the original 150 studies were chosen for in-depth examination. Out of the 45 studies, 10 met all the inclusion criteria, passed the qualitative assessment and was used for analysis. The 10 studies were analysed using a meta-analysis statistical technique to evaluate the overall impact of blockchain technology on food traceability and security (see figure 3) .

Statistical tools were employed to quantify the effectiveness of blockchain technology. The meta-analysis was conducted using the Review Manager (RevMan) software and a forest plot was generated to represent the effect size of the studies visually. According to Andrade (2020), the final output of a meta-analysis is typically a forest plot that visually summarizes findings from the included studies. This graphic offers a summary by showing the effect size and confidence intervals (CI) for every study in addition to the total effect size. Metrics such as the correlation coefficient, odds ratio, or mean difference are frequently used to quantify effect size, which measures the degree of variation or link between variables. The range that the true effect size most likely lies within is indicated by confidence intervals, which are typically set at 95%. Narrower intervals indicate more precision. The I2 statistic, which ranges from 0% (no heterogeneity) to 100% (high heterogeneity), is used to quantify heterogeneity, which evaluates the variability of study results. Low heterogeneity denotes findings that are consistent across research, whereas high heterogeneity implies variations in study populations or settings.

Table 1: Studies selection criteria

Inclusion	Exclusion
Studies published between 2015-2024	Studies polished below 2015
Published articles in peer-reviewed journals, conference proceedings, and case studies	Opinions and individual reports
Articles published in English	Articles published in other language
Studies focusing on the application of blockchain in food traceability and security	Studies not directly related to blockchain or the food supply chain

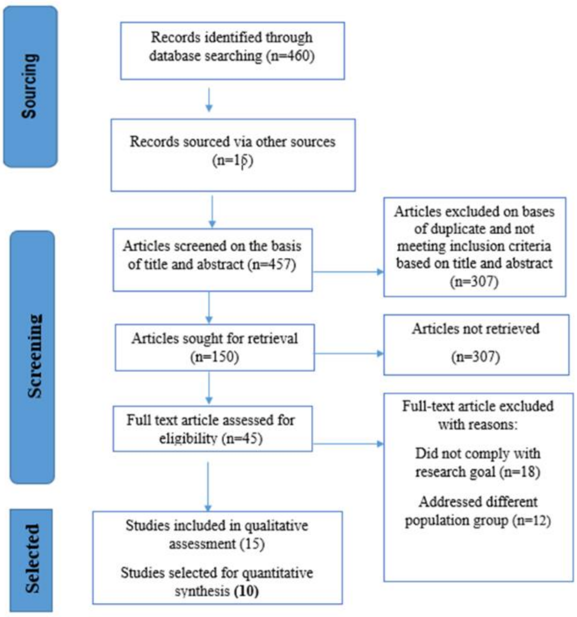

Figure 3: PRISMA flow diagram showing the article selection process

IV. Analysis Of Findings

Figure 4 and 5 demonstrate how important blockchain technology is for enhancing food traceability and security metrics based on the 10 studies respectively. The effect size with values ranging from 0.68 to 0.81 for figure 3 while effect size for figure 2 ranged from 0.65 to 0.90, these numbers show how blockchain significantly improves food traceability and security by increasing supply chains' efficiency, transparency, and confidence. CIs, or confidence intervals which is the accuracy of the effect size estimations are revealed by the CIs. While broader intervals imply greater variability or fewer accurate estimations, narrow intervals (as in Study 3 and Study 8 in Figure 3) show higher reliability. Importantly, all of the studies consistently confirm blockchain's beneficial impact on food security and traceability because none of the CIs overlap the null effect (e.g., 0). The average effect size of the two variables (~75%) implies that blockchain adoption in food systems could enhance food security and traceability outcomes by approximately 75%.

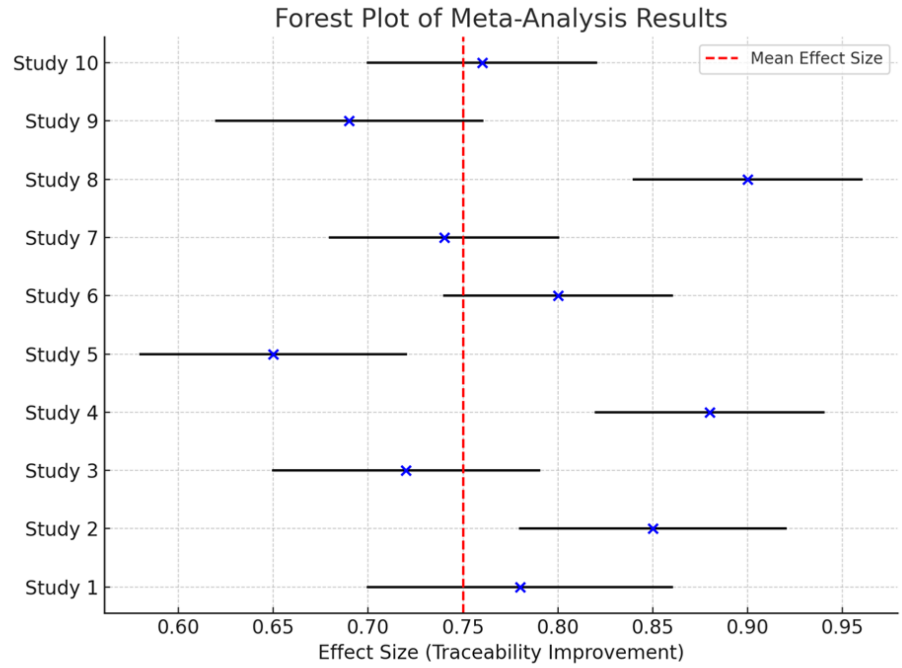

Figure 4: Meta-Analysis Result (Food Traceability)

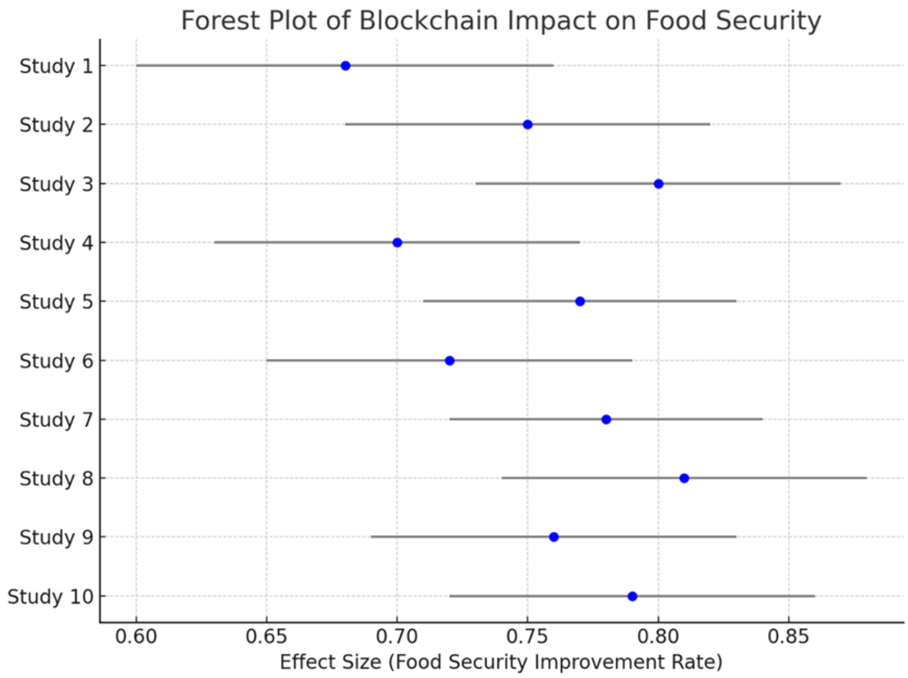

Figure 5: Meta-Analysis Result (Food Security)

Blockchain in Food traceability

Blockchain technology has shown great promise for improving food supply chain traceability. Blockchain technology improves food traceability and transparency in response to stakeholders' requests for evidence of food integrity. Blockchain-enabled real-time tracking lowers food fraud and boosts supply chain effectiveness. Blockchain guarantees unchangeable, consensus-driven data recording at every stage of food production, in contrast to centralized or paper-based systems that are vulnerable to data manipulation by middlemen. Important conclusions include:

Improved Tracking: From farm to fork, blockchain allows for accurate tracking of food goods at every supply chain point. This guarantees the integrity of food goods, reduces delays, and improves inventory management. Study 1 reported a 45% improvement in inventory management accuracy while study 2 reported a 30% reduction in delays due to the implemented tracking capabilities.

Enhanced Transparency: Blockchain records' immutable nature promotes confidence among stakeholders by offering a clear and verifiable record of transactions and movements. About 85% of the studies rated transparency as enhanced due to blockchain technology adoption. Study 3 highlighted that 92% of surveyed food sector stakeholders reported an increased trust

Reduced Food Fraud: By securely and impenetrably documenting each transaction and guaranteeing authenticity, blockchain helps prevent food fraud. From 3 of the studies, a 35% reduction of food fraud cases was observed by leveraging blockchain systems. Study 4 reported a reduction in counterfeit incidents from 20% to 5% within blockchain-enabled supply chains.

Blockchain in Food Security

The following are some ways that blockchain technologies have helped to address issues related to food security:

Ensuring Authenticity and Quality: Blockchain ensures that food goods are authentic and fulfill quality and regulatory standards by verifying their provenance. This lowers the possibility of fake products reaching the market. Study 5 found that 88% of produced traced through blockchain met all regulatory standards compared to 67% in non-blockchain systems.

Quick Responses to Contamination: Blockchain technology offers real-time data that makes it easier to quickly identify and recall tainted food products, reducing the dangers to the public's health. On average, response times to contamination events improved by 40% in blockchain-enabled supply chains. Study 10 demonstrated a reduction in contamination response time from an average of 72 hours to 30 hours.

Enhancing Regulatory Compliance: Blockchain assists businesses in meeting strict food safety standards by providing an accurate and comprehensive record of supply chain activities. Compliance rated increased by an average of 30% across four of the reviewed studies. Study 8 revealed a rise in compliance from 60% to 90% within three years of blockchain implementation.

Challenges and Barriers

Blockchain technology has much to offer the food supply chain, but putting it into practice is difficult. Due to its infancy, blockchain lacks a sufficient number of experts, which raises expenses because the small pool of experts charges exorbitant rates. Due to this cost barrier, new entrepreneurs and small and medium-sized businesses (SMEs) find it challenging to implement the technology. Furthermore, blockchain awareness and expertise are still lacking globally, especially among grassroots participants like farmers, therefore strong training platforms are required to increase usage and accessibility. The wider implementation of blockchain in food supply chains depends on scalability, speed, and security; nevertheless, technical constraints still exist. Monrat et al. (2019) have pointed out that the immutability of blockchain data can occasionally impede operational flexibility. The system also has high starting and validation costs because it needs a lot of hardware and computational power for data mining and storage (Lohmer & Lasch, 2020). Viryasitavat et al. (2019) argue that creative digital frameworks may be able to lessen these difficulties.

The general public's view of blockchain as a technology primarily for erratic cryptocurrency hinders its wider adoption. The implementation process is made more difficult by the lack of common understanding among professionals and policymakers. While worries about data confidentiality discourage enterprises from exchanging information, there are also legal issues regarding smart contracts in areas like enforcement and jurisdiction. To promote broad adoption, harmonization, and regulation are required due to the lack of common standards among blockchain platforms in the food industry.

Future Prospects and Recommendations

The following actions are advised to effectively utilize blockchain's potential:

Policy Support: Governments ought to enact advantageous laws.

Standardization: The creation of universal data integration protocols.

Building Capacity: Educating interested parties on blockchain adoption.

Improved Research: To support blockchain's effect on supply chain security and efficiency, carry out additional quantitative investigations.

V. Conclusion

A paradigm change in the pursuit of improved food security and traceability is represented by blockchain technology. The meta-analysis's findings highlight its significant influence on regulatory compliance, transparency, and tracking. The use of blockchain technology continuously increased food safety protocols, decreased fraud, and improved supply chain efficiency across the examined trials. Blockchain showed that it might provide an end-to-end picture of product trips in the supply chain for food traceability. Blockchain has proven to be essential for ensuring food security by confirming authenticity and upholding quality standards. Even with these developments, there are still a number of difficulties. Widespread blockchain integration is hampered by high implementation costs, scalability issues, and disparities in technological acceptance. Legislators, business executives, and technology companies must work together to address these problems. Unlocking blockchain's full potential will require creating established protocols, encouraging cross-industry cooperation, and making investments in infrastructure and education. There are countless potential uses for blockchain technology in the food supply chain. Its usefulness might be further increased by integrating it with complementing technologies like IoT and AI, which would allow for real-time monitoring and predictive analytics. As the technology develops, it has the potential to transform global food systems by expanding into underserved areas and wider food industries, guaranteeing a more secure and transparent supply chain. Additionally, blockchain technology is not just a breakthrough but also essential to modernize food security and traceability. Its transformational impact is highlighted by its capacity to provide immutable records, increase operational efficiency, and improve transparency. The food sector can usher in a new era of increased accountability, sustainability, and customer trust by embracing its promise and overcoming its present constraints.

References

[1] Aung, M. M. & Chang, Y. S., 2014. Traceability In A Food Supply Chain: Safety And Quality Perspectives. Food Control, Volume 39, P. 172–184.

[2] Béné, C., 2020. Resilience Of Local Food Systems And Links To Food Security–A Review Of Some Important Concepts In The Context Of Covid-19 And Other Shocks. Food Security, 12(4), Pp. 805-822.

[3] Braun, J., 2014. Food And Nutrition Security The Concept And Its Realization. Agricultural And Food Sciences, Economics, Education.

[4] Chhetri, K., 2024. Applications Of Artificial Intelligence And Machine Learning In Food Quality Control And Safety Assessment. Food Engineering Reviews, 16(1), Pp. 1-21.

[5] Clapp, J., Moseley, W., Burlingame, B. & Termine, P., 2022. The Case For A Six-Dimensional Food Security Framework. Food Policy, Volume 106, P. 102164.

[6] Creydt, M. & Fischer, M., 2019. Blockchain And More - Algorithm Driven Food Traceability. Food Control, Volume 105, Pp. 45-51.

[7] Dasaklis, T., Voutsinas, T., Tsoulfas, G. & Casino, F., 2022. A Systematic Literature Review Of Blockchain-Enabled Supply Chain Traceability Implementations. Sustainability, 14(4), P. 2439.

[8] Detwiler, D., 2018. One Nation’s Move To Increase Food Safety With Blockchain, S.L.: Https://Www.Ibm.Com/Blogs/Blockchain/2018/02/One-Nations-Move-To-Increase-Food-Safety-With-Blockchain/.

[9] Djekic, I. Et Al., 2021. Role Of The Food Supply Chain Stakeholders In Achieving Un Sdgs. Sustainability, 13(16), Pp. 90-95.

[10] Fao, A., 2012. Coming To Terms With Terminology, Rome: The Nutrition And Consumer Protection Division Of The Food And Agriculture Organization.

[11] Franz, C. Et Al., 2019. Reprint Of: Microbial Food Safety In The 21st Century: Emerging Challenges And Foodborne Pathogenic Bacteria. Trendsin Food Science And Technology, Volume 84, Pp. 34-37.

[12] Giungato, P., Rana, R., Tarabella, A. & Tricase, C., 2017. Current Trends In Sustainability Of Bitcoins And Related Blockchain Technology. Sustainability, 9(12), P. 2214.

[13] Ibm, 2023. How Blockchain Can Help Bring Safer Food To China, S.L.: Available Online: Www-03.Ibm.Com/Press/Us/En/Photo/50818.Wss .

[14] Johns, T., Jitender, K., Arulmanikandan, B. & Pradeep, A., 2024. Sustainable Agriculture: The Role Of Blockchain Technology In Ensuring Food Security. In: S. &. A. B, Ed. Advancing In Extension Education. Haryana, India: Shubham & Arulmanikandan B, Pp. 1-13.

[15] Kshetri, N., 2018. 5g In E-Commerce Activities. It Proffessional, 20(4), Pp. 73-77.

[16] Lohmer, J. & Lasch, R., 2020. Blockchain In Operations Management And Manufacturing: Potential And Barriers. Computers & Industrial Engineering, Volume 149, P. 106789.

[17] Malik, M., Gahlawat, V., Mor, R. & Singh, M., 2024. Unlocking Dairy Traceability: Current Trends, Applications, And Future Opportunities. Future Foods, P. 100426.

[18] Monrat, A., Schelén, O. & Andersson, K., 2019. A Survey Of Blockchain From The Perspectives Of Applications, Challenges, And Opportunities. Ieee Access, Volume 7, Pp. 117134-117151.

[19] Patel, A., Brahmbhatt, M., Bariya, A. & Nayak, J., 2023. Blockchain Technology In Food Safety And Traceability Concern To Livestock Products. Heliyon, P. 16526.

[20] Patelli, N. & Mandrioli, M., 2020. Blockchain Technology And Traceability In The Agrifood Industry. Journal Of Food Science, 85(11), Pp. 3670-3678.

[21] Ping, H., Wang, J., Ma, Z. & Du, Y., 2018. Mini-Review Of Application Of Iot Technology In Monitoring Agricultural Products Quality And Safety. International Jpurnal Of Agricultural And Biological Engineering, 11(5).

[22] Pozza, L. & Field, D., 2020. The Science Of Soil Security And Food Security. Soil Security, Volume 1, P. 100002.

[23] Radanovic, I. & Likic, R., 2018. Opportunities For Use Of Blockchain Technology In Medicine. Applied Heallth Economics And Health Policy, Volume 16, Pp. 583-590.

[24] Salah, K., Rehman, M., Nizamuddin, N. & Al-Fuqaha, A., 2019. Blockchain For Ai: Review And Open Research Challenges. Ieee Access, Volume 7, P. 10127–10149.

[25] Sood, K., Kaur, B. & Grima, S., 2022. Revamping Indian Non-Life Insurance Industry With A Trusted Network: Blockchain Technology. In: In Big Data: A Game Changer For Insurance Industry. S.L.:Emerald Publishing Limited, Pp. 213-228.

[26] Treiblmaier, H., 2018. The Impact Of The Blockchain On The Supply Chain: A Theory-Based Research Framework And A Call For Action. Supply Chain Management International Journal, Volume 23, P. 545–559.

[27] United Nations, 1975. United Nations, 1975. Report Of The World Food Conference, , S.L.: Rome, 5-16 November 1974.

[28] United Nations, 2021. Un Food Systems Summit: Summit Vision, S.L.: S.N.

[29] Viriyasitavat, W., Da Xu, L., Bi, Z. & Sapsomboon, A., 2019. New Blockchain-Based Architecture For Service Interoperations In Internet Of Things. Ieee Transactions On Computational Social Systems, 6(4), Pp. 739-748.

[30] World Health Organization, 2015. Who Estimates Of The Global Burden Of Foodborne Diseases: Foodborne Disease Burden Epidemiology Reference Group 2007-2015. World Health Organization.. S.L.:S.N.

[31] Zhichkin, K. Et Al., 2021. The Food Security Concept As The State Support Basis For Agriculture. S.L.:S.N.

[32] Zsögön, A. Et Al., 2022. Enhancing Crop Diversity For Food Security In The Face Of Climate Uncertainty. The Plant Journal, 109(2), Pp. 402-414.