# FROM FARM TO FORK: HOW BLOCKCHAIN ENSURES FOOD SECURITY AND TRUST

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**Abstract.** The foodservice industry faces significant challenges in ensuring food safety, quality, and transparency across complex supply chains. Thus, blockchain technology has emerged as a revolutionary tool to address these issues by providing a decentralized, immutable ledger for tracking food products from farm to table. This paper explores the role of blockchain in food quality assurance and control, emphasizing its ability to enhance traceability, prevent fraud, and improve regulatory compliance. By securing real-time, tamper-proof records, blockchain fosters trust among consumers and industry stakeholders while reducing inefficiencies in food supply management. Through the literature review, this paper examines the application of blockchain in global food supply chains, showcasing its effectiveness in improving product traceability and safety. Despite its potential, blockchain adoption faces challenges, with high implementation costs, regulatory uncertainties, and technical barriers. An implementation framework outlining key phases, from initiation to full integration, offering strategic insights for businesses and policymakers was presented. As blockchain evolve, industry collaboration, regulatory support, and technological advancements will be crucial in overcoming barriers and maximizing its impact on food quality assurance. This paper underscores the need for further research to optimize blockchain's scalability and long-term sustainability in foodservice applications.
**Keywords**: *blockchain technology, foodservice, supply chain, traceability, quality assurance*

## Introduction

Food quality assurance involves systematic procedures to ensure products are safe and meet established benchmarks, guided by regulatory frameworks that prevent contamination and safeguard integrity (Paździor, 2016). These systems also monitor production for consistency, traceability, and risk mitigation, reducing waste and inefficiencies while building consumer trust (Visciano and Schirone, 2020; Pennock, 2007; Manning et al., 2006). Blockchain offers potential to improve traceability and transparency, though studies often remain at small-scale pilots (Ahmed and MacCarthy, 2022). Practical challenges include network congestion, slow transaction speeds, and integration difficulties, with limited research on high-volume conditions. Consumer response is also mixed: too much information can overwhelm decision-making (Cao et al., 2023), while risk-tolerant individuals may not value detailed traceability (Zhai et al., 2023). Thus, blockchain tools must be technically sound, accessible, and user-friendly. Integrating blockchain into food supply chains could strengthen quality assurance by enhancing transparency, data integrity, and regulatory compliance.

### *Blockchain technology and its role in food quality assurance*

Blockchain is a decentralized digital ledger originally developed for Bitcoin but now widely applied beyond cryptocurrency, offering secure, anonymous, and tamper-proof transaction recording without central authority (Zheng and Lu, 2022; Frizzo-Barker et al., 2020; Yli-Huumo et al., 2016). In the food industry, blockchain strengthens supply chain transparency and security by enabling immutable tracking from farm to consumer (Li et al., 2023; Kamilaris et al., 2019). This capability enhances trust, ensures authenticity, and supports food safety and quality assurance through precise traceability (Hao et al., 2024; Xu et al., 2022; Rejeb et al., 2020; Rogerson and Parry, 2020). Food contamination arising from microbial, chemical, or physical hazards remains a critical risk across production and distribution stages (Gizaw, 2019). Blockchain mitigates these risks by fostering transparency, accountability, and stakeholder trust. This paper thus examines blockchain's role in improving food quality within supply chain operations, focusing on its adoption, impact on traceability, authenticity, and consumer confidence, and effectiveness in reducing contamination risks. Drawing on prior research (Hao et al., 2024; Li et al., 2023; Xu et al., 2022; Rejeb et al., 2020; Rogerson and Parry, 2020), it provides evidence-based insights and practical recommendations for businesses and policymakers on leveraging blockchain to strengthen food quality and safety.

### *Blockchain technology: concepts and mechanisms*

Blockchain is a decentralized ledger distributed across multiple computers, enhancing security, transparency, and trust by eliminating central authority control (Laroiya et al., 2020; Wang et al., 2019b). Consensus mechanisms such as Proof of Work (PoW) provide strong security but consume high energy, while Proof of Stake (PoS) offers faster, more efficient validation (Thanujan et al., 2020; Nguyen et al., 2019). Its applications span finance, healthcare, and supply chains, making foodservice adoption a logical step for improving traceability and accountability (Gaurav et al., 2020; Monrat et al., 2019; Beck et al., 2017).

### *Food quality assurance and control in the foodservice industry*

Food quality assurance establishes systems to ensure safety and consistency across the supply chain (Vasconcellos, 2003; Orriss and Whitehead, 2000; Bobeng and David, 1977). While quality assurance sets standards, quality control monitors attributes such as microbiological, nutritional, and sensory qualities to ensure compliance (Bobeng and David, 1977). Together, they maintain integrity and consumer confidence in food products.

### *Blockchain applications in food quality assurance and control*

Blockchain ensures immutable product records, strengthening traceability, accountability, and food safety compliance (Oriekhoe et al., 2024; PD, 2024). It prevents fraud through decentralized verification (Dai et al., 2017) and, when integrated with IoT, enhances real-time monitoring and transparency (Kechagias et al., 2023; Prashar et al., 2020; Shahid et al., 2020). Smart contracts and permissioned blockchains further streamline compliance and optimize agri-food supply chains (Chen et al., 2021; Ding et al., 2020; Wang et al., 2019a; Tsang et al., 2019).

### *Framework for blockchain in foodservice*


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Blockchain adoption in food supply chains follows initiation, adoption decision, and implementation phases (Vu et al., 2023), consistent with innovation frameworks (AL-Ashmori et al., 2023; Ahmed and MacCarthy, 2022). Firms explore benefits and assess feasibility (Li et al., 2023; Ahmed and MacCarthy, 2022), with pilots often limited by scalability, regulation, and integration challenges (Mbadlisa and Jokonya, 2024; Li et al., 2023; Kamilaris et al., 2019). Case studies, such as Italian cheese production, highlight blockchain's role in reducing counterfeiting and enhancing trust (Caldarelli et al., 2020).

### *Relevance of blockchain in Malaysian foodservice*

In Malaysia, blockchain is emerging in halal supply chains to verify authenticity and strengthen consumer trust (Elfarnawani and Kartiwi, 2024). Adoption is influenced by institutional pressures and halal strategies, though limited awareness, technical barriers, and costs hinder SMEs (Hew et al., 2020; Wong et al., 2020; Kamilaris et al., 2019). Broader adoption requires overcoming financial and regulatory challenges, but the potential to improve traceability and transparency remains significant.

## Materials and Methods

### *Research approach*

This literature review provides a structured and critical analysis of existing academic research on blockchain technology's role in food safety and supply chain management. The review involved secondary data collection, using systematically synthesizes findings from peer-reviewed journal articles. The data were collected from high-impact academic databases, including ScienceDirect, IEEE Xplore and SpringerLink. These databases were selected due to their extensive indexing of scholarly literature and their inclusion of high-quality, peer-reviewed studies. The search terms used included 'blockchain in food safety,' 'blockchain traceability,' and 'blockchain supply chains.' The criteria for inclusion were peer-reviewed articles in English, published between 2022 and 2024, that were specifically relevant to food safety. Non-peer-reviewed studies and articles not in English were excluded from the review. By systematically analyzing the selected literature, this review identifies emerging trends, key challenges, and potential opportunities for blockchain adoption in the food supply chain. Additionally, it highlights gaps in the existing research and provides directions for future studies in this evolving field.

### *Data Analysis*

The collected studies were analyzed and categorized into key themes, including blockchain applications in traceability, food safety enhancement, and challenges to implementation. A comparative analysis was conducted to identify consistent findings, divergent viewpoints, and research gaps, ensuring a comprehensive understanding of the topic. Each study was critically evaluated based on its methodology, findings, and contributions to the field. However, this review has certain limitations, including potential selection bias due to the focus on English-language studies and reliance on a limited number of academic databases. Additionally, the exclusion of gray literature may have resulted in the omission of some relevant insights, which could have provided a broader perspective on blockchain adoption in food safety and supply chains.

## Results and Discussion

### *Blockchain*

Blockchain is a decentralized ledger that ensures transparency, immutability, and traceability across peer-to-peer networks (González-Mendes et al., 2024; Mohammed et al., 2024). Transaction validation relies mainly on Proof of Work (PoW), which is secure but energy-intensive (Abellán Álvarez et al., 2024; Gad et al., 2022), and Proof of Stake (PoS), which is more scalable and efficient (Chandan et al., 2024; Panghal et al., 2024). In agri-food systems, blockchain is conceptualized as a generic infrastructure (Habib et al., 2022), a global traceability tool with smart contracts (González-Mendes et al., 2024; Ellahi et al., 2023), and consumer-focused food traceability emphasizing safety, provenance, Halal verification, and sustainability (Mbadlisa and Jokonya, 2024; Wong You King et al., 2024) (*Table 1*).

***Table 1**. Identified concepts and relative definitions used for blockchain.*

| Concepts | Definition | References |
|---|---|---|
| Blockchain | A decentralized and immutable digital ledger that records transactions across a peer-to-peer network, ensuring data integrity and transparency without the need for a central authority. | Chandan et al. (2024); González-Mendes et al. (2024); Mohammed et al. (2024); Ellahi et al. (2023); Zhai et al. (2023); Habib et al. (2022) |
| Proof Of Work (PoW) | A consensus mechanism where network participants solve complex computational puzzles to validate transactions and add new blocks, ensuring security but consuming significant energy. | Abellán Álvarez et al. (2024); Chandan et al. (2024); Tang (2023); Gad et al. (2022) |
| Proof Of Stake (PoS) | A consensus mechanism where validators are chosen based on the amount of cryptocurrency they hold and are willing to "stake," offering energy efficiency and scalability over PoW. | Abellán Álvarez et al. (2024); Chandan et al. (2024); Panghal et al. (2024); Gad et al. (2022) |
| Blockchain In Food Traceability | The application of blockchain technology to track and record the journey of food products through the supply chain, enhancing transparency, safety, and consumer trust. | González-Mendes et al. (2024); Mbadlisa and Jokonya (2024); Panghal et al. (2024); Sudarssan (2024); Wong You King et al. (2024); Ellahi et al. (2023); George and Al-Ansari (2023); Tang (2023); Zhai et al. (2023) |

### *Food safety*

Food safety, defined under international standards such as Codex Alimentarius, seeks to prevent harm through safe preparation and consumption (Lee et al., 2021). Risk-based frameworks emphasize hazard identification and preventive controls (Vågsholm et al., 2020; Koutsoumanis and Aspridou, 2016), while consumer trust depends on freshness, hygiene, labeling, and certification schemes (Qian et al., 2023; Singh et al., 2023; Redmond and Griffith, 2004). Broader approaches like “One Health” link food safety with human, animal, and environmental health (OHHLEP et al., 2022; Destoumieux-Garzón et al., 2018). Emerging technologies such as blockchain, IoT, and AI enhance traceability and rapid contamination response, supporting safer and more sustainable food systems (Vargas-Bello-Pérez et al., 2025; Sri Vigna Hema and Manickavasagan, 2024; Singh et al., 2023; Yu et al., 2022) (*Table 2*).

***Table 2**. Concepts and definitions of food safety in the blockchain literature.*

| Concept | Definition | References |
|---|---|---|
| Risk-Based Food Safety | A scientific and preventive framework focused on identifying, assessing, and controlling food safety hazards (biological, chemical, or physical) based on their risk level. | Vågsholm et al. (2020); Koutsoumanis and Aspridou (2016) |
| Systemic (One Health) Food Safety | An integrated, cross-sectoral approach linking human, animal, and environmental health to ensure sustainable and holistic food safety strategies. | OHHLEP et al. (2022); Destoumieux-Garzón et al. (2018) |
| Consumer-Driven | Food safety shaped by consumer trust, behavior, | Qian et al. (2023); Singh et al. (2023) |


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|---|---|---|
| Food Safety | perception of risk, and reliance on transparency tools such as labels, certifications, and traceability systems. | |
| Technological Food Safety | The use of advanced technologies; blockchain, IoT, AI to improve traceability, monitor contamination, and automate food safety interventions across the supply chain. | Sri Vigna Hema and Manickavasagan (2024); Singh et al. (2023); Yu et al. (2022) |

### *Implications of blockchain for food supply chains*

Blockchain has transformative potential in food supply chains by enhancing transparency and traceability, enabling farmers, distributors, retailers, and consumers to monitor products across their journey and thereby improving safety, quality, and trust (Ellahi et al., 2024). Its decentralized structure reduces costs and inefficiencies, eliminates intermediaries, and prevents fraud through immutable data (Albshaier et al., 2024). Smart contracts automate tasks such as payments, lowering errors and delays, while real-time monitoring aids early detection of contamination and assures authenticity and sustainable sourcing (Duong et al., 2025; Balcıoğlu et al., 2024). These features collectively strengthen food security, deter fraud, and promote sustainability (Duan et al., 2024).

### *Comparative analysis with existing systems*

Traditional systems rely on centralized databases and paper-based records prone to inefficiency, error, and manipulation, while blockchain ensures a decentralized, immutable ledger offering end-to-end traceability (Ellahi et al., 2024). Walmart’s blockchain adoption reduced mango traceability time from seven days to 2.2 seconds, demonstrating its advantage in accountability and consumer trust. By removing intermediaries, blockchain accelerates transactions, reduces reliance on third-party verification, and enhances data security through encryption and consensus mechanisms. Unlike centralized databases vulnerable to breaches, blockchain restricts access to authorized users and scales effectively for global supply chains (Ellahi et al., 2024).

### *Impact on consumer perception and industry standards in Malaysia*

In Malaysia, blockchain fosters consumer trust by providing verifiable product information through tools such as QR codes, with particular importance for halal certification (Bazel et al., 2023). It also supports sustainability initiatives, for example in palm oil, by ensuring compliance with RSPO standards and addressing deforestation and ethical concerns (Bazel et al., 2023). National efforts such as the Blockchain Roadmap (2021–2025) highlight blockchain’s role in digital transformation, extending to health applications like vaccine distribution and secure payment systems (AlAfnan and Mohd Zuki, 2024; MOSTI, 2021). These initiatives reinforce transparency, strengthen halal assurance, enhance sustainability, and position Malaysia as a leader in digital innovation (Bazel et al., 2023).

### *Recommendations for industry adoption*

### *Strategies for effective implementation*

Effective blockchain adoption in Malaysia requires a supportive legal and regulatory framework aligned with existing laws such as the Personal Data Protection Act (PDPA), alongside clear guidelines for smart contracts to enhance trust and legal certainty (AlAfnan and Mohd Zuki, 2024; Bazel et al., 2023; Wong et al., 2020). For SMEs, cost remains a barrier; thus, incentives such as grants, tax exemptions, and financial assistance are essential (Bazel et al., 2023). Organizational readiness and sector-specific factors also influence adoption (AL-Ashmori et al., 2023). Collaboration among government, industry, and academia is vital for knowledge sharing and innovation, with emphasis on local applications in logistics, agriculture, and halal traceability to demonstrate blockchain's value and relevance (Waqar et al., 2024; Wong You King et al., 2024; Bazel et al., 2023).

### *Future research directions*

Future research should integrate blockchain with IoT for real-time monitoring of conditions such as temperature and humidity, reducing spoilage, waste, and supporting redistribution to underserved groups (Safeer and Pulvento, 2024; Bazel et al., 2023; Pranto et al., 2021; Torky and Hassanien, 2020). Studies could expand to sustainability and animal welfare by tracking environmental metrics and compliance (Yang et al., 2024), while smart contracts and decentralized finance may improve supply chain financing for smallholders (Pranto et al., 2021). Beyond food systems, blockchain applications in healthcare, education, and renewable energy remain underexplored in Malaysia, offering potential for managing records, credentials, and energy trading (Sakib Sizan et al., 2025; AL-Ashmori et al., 2023; Pranto et al., 2021). Research should also address regulatory and economic barriers while developing lightweight, user-friendly blockchain tools for broader adoption.

## Conclusion

Blockchain provides decentralized, immutable systems that enhance food supply chain traceability, reduce fraud and contamination, and build consumer trust through real-time, verifiable data (Ellahi et al., 2024). In Malaysia, its role is particularly relevant for halal certification, sustainable agriculture, and logistics (Bazel et al., 2023). However, high costs, technical barriers, and regulatory complexity remain obstacles. Addressing these challenges requires tailored regulatory frameworks, financial incentives for SMEs, and strong collaboration between government, academia, and industry (AlAfnan and Mohd Zuki, 2024; AL-Ashmori et al., 2023; Wong et al., 2020). Future research should prioritize scalable blockchain architectures, IoT integration, and expansion into adjacent sectors such as healthcare and renewable energy to align with Malaysia's sustainability goals (Sakib Sizan et al., 2025; Yang et al., 2024; Torky and Hassanien, 2020). Overall, blockchain represents a strategic innovation that, supported by responsive policy and cross-sector collaboration, can significantly enhance the efficiency, integrity, and sustainability of Malaysia's food supply chain ecosystem.

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## Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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