2025 Volume 3, Issue 9
Lecture Notes in Education, Arts, Management and Social Science
ISSN(Online): 2705-053X

Exploration of the Application of Blockchain Technology in the Field of Food Safety

Zhen Chen, Jiaqi Liu
Shandong Labor Vocational and Technical College, Jinan 250301, Shandong, China

Abstract: Food safety is a core issue related to public health and social stability. Current food supply chains face prominent problems such as information opacity, low traceability efficiency, and difficulty in liability determination, making traditional traceability systems unable to meet the needs of full-chain supervision. Focusing on the application of blockchain technology in food safety, this paper systematically analyzes its application logic and implementation paths in all links of food production, processing, circulation, and sales based on the technical characteristics of blockchain "decentralization, immutability, full traceability, and transparency." Research shows that blockchain technology can break the information barriers among all participants in the food supply chain, build a full-life-cycle traceability system "from farm to table," provide technical empowerment for food safety supervision, and help improve the level of food quality and safety assurance, which has important practical significance and application prospects.

Keywords: Blockchain technology; Food safety; Smart contract

Online publication: October 26, 2025

1. Introduction

Food safety is related to public health and social stability. Current food supply chains have prominent problems such as information opacity and low traceability efficiency, and traditional traceability systems can no longer meet the needs of full-chain supervision. With its core characteristics of "decentralization, immutability, full traceability, and transparency," blockchain technology provides a new path to solve the pain points in the field of food safety.

This study systematically sorts out the core application scenarios of blockchain technology in food safety: in full-chain traceability, by recording key data of food in each link from planting, processing, transportation to sales, it endows food with a unique digital identity, greatly improving traceability efficiency and transparency [1]; intelligent contracts are used to realize automated supply chain management, completing automatic quality inspection, risk early warning, and compliance automatic execution in scenarios such as cold chain transportation, transforming post-event accountability into in-event intervention; through the integration of blockchain with the Internet of Things (IoT) and biometric technology, a full-link anti-counterfeiting authentication system is built to solve the defects of traditional anti-counterfeiting technologies such as easy replication and difficult traceability, such as the anti-counterfeiting application of high-end wine in Bordeaux, France; consortium chain technology is used to build a supply chain collaboration system, realizing information sharing among all participating subjects while ensuring data privacy, and optimizing risk control and supply chain operation efficiency.

2. Research on the application of blockchain technology in food safety

2.1. Full-chain traceability

In the field of food safety, consumers generally have concerns about potential risks in the food circulation process. These concerns not only affect consumers' purchasing confidence but also restrict the healthy development of the food industry. With its characteristics of decentralization, immutability, and full traceability, blockchain technology provides an effective solution to the above problems, thus showing important value in food traceability and safety assurance [2,3].

Data from every key link of food, from planting, processing, transportation, to final sales, can be recorded on the blockchain. These data include, but are not limited to, origin certificates, pesticide use records, and quality inspection reports. Each batch or piece of food will be assigned a unique digital identity. When purchasing, consumers only need to scan this identity with their mobile phones to obtain complete circulation information of the food from the source to the present, realizing information transparency and traceability.

In this way, blockchain technology not only enhances the transparency and credibility of the food supply chain but also provides consumers with a reliable information query channel, ensuring food safety from the source and reshaping consumers' trust in the modern food system.

2.2. Automated management with smart contracts

Blockchain technology not only realizes information traceability but also upgrades food supply chain management from passive traceability to active, automated execution and control through its core component—smart contracts. A smart contract is a self-executing agreement deployed on the blockchain, whose terms are directly defined and controlled by code. When preset conditions are triggered, the relevant terms will be automatically executed without manual intervention, thereby greatly improving the efficiency, transparency, and credibility of supply chain management.

In terms of application, it is mainly reflected in process automation and risk control, and can achieve automatic quality inspection and risk early warning. At the same time, it is important to allow the automatic execution of smart contract compliance. To ensure the standardization of each link in the supply chain, smart contracts can force participants to fulfill their obligations on time. For example, the contract can stipulate that suppliers must upload qualified inspection certificates from authoritative institutions within 24 hours before goods are delivered from the warehouse [5-6]. If the supplier fails to submit them on time, the smart contract will automatically take effect, suspending its transaction qualification in the supply chain system and preventing it from entering the next link. This automated rule of "code is law" rigidly guarantees process compliance and eliminates management loopholes caused by favoritism or omissions.

Through the above mechanism, smart contracts transform the traditional supply chain management process that relies on manual review and is prone to disputes into efficient, transparent, and credible automated operations. It not only reduces supervision costs but also builds a sound business ecology with clear rewards and punishments, providing key technical support for building a robust modern food supply system.

2.3. Anti-counterfeiting and authentication

Against the background of global trade integration and diversified commodity circulation, traditional anti-counterfeiting technologies have been difficult to meet people's high demand for food safety due to defects such as easy replication, difficult traceability, and easy data tampering. Therefore, the in-depth integration of blockchain, the Internet of Things (IoT), and biometric technology has built a full-link anti-counterfeiting authentication system of "traceable source, controllable process, credible data, and verifiable identity", becoming the core technical path to solve anti-counterfeiting problems [7].

Compared with traditional anti-counterfeiting technologies, the combined model of blockchain + IoT + biometrics has three core advantages: first, data credibility. The decentralized architecture of blockchain eliminates the risk of data monopoly and tampering by a single institution. All nodes jointly maintain the ledger to ensure the authenticity and non-repudiation of traceability data; second, full-link coverage. IoT technology realizes full-process data collection of commodities from production to consumption, breaking the limitation of traditional anti-counterfeiting that "only recognizes labels but not processes" and forming closed-loop control; third, a high anti-counterfeiting threshold. The uniqueness and high counterfeiting cost of biometric technology technically block the possibility of counterfeiting by counterfeiters, solving the pain point of easy replication of traditional labels. Ultimately, it achieves a win-win situation for multiple subjects: brand owners improve brand reputation and market competitiveness through anti-counterfeiting authentication; consumers obtain genuine product guarantees and transparent information; regulatory authorities achieve efficient supervision and precise anti-counterfeiting, forming a win-win industrial ecology.

In terms of high-end wine anti-counterfeiting, a winery in Bordeaux, France, embeds an NFC chip into the cork of the wine bottle, and the chip has a built-in blockchain node private key. During the brewing process, data such as grape variety, harvesting time, and fermentation cycle of each batch are automatically uploaded to the blockchain by sensors; during the logistics phase, the GPS module records real-time transportation routes and temperature and humidity changes to ensure that the wine is not replaced or deteriorated. After purchasing, consumers can touch the chip through the mobile phone's NFC function module to jump to the blockchain verification page, view the full-process data, and obtain a genuine product traceability certificate provided by the brand owner [8]. This model not only solves the counterfeiting chaos in the high-end wine market but also increases the product's brand premium and consumer trust through traceability data.

2.4. Improvement of supply chain transparency

In the food supply chain, information fragmentation among various participating subjects is the core pain point leading to inefficient traceability and delayed risk response. With its characteristics of decentralization, immutability, and controlled permissions, consortium chain technology provides a feasible path to solve this problem. Its core implementation logic and application effects are as follows.

Through a preset access mechanism, the consortium chain incorporates key nodes such as farms, processing plants, and logistics providers into a unified blockchain network, building a collaborative system of "data sharing but privacy controllable". Specifically, the core data sharing model of each node is as follows.

The production end is responsible for uploading key planting/breeding information, including seed/seedling sources, fertilizer/feed use records, pesticide/veterinary drug application time and dosage, and growth environment monitoring data. The data is uploaded to the chain after being signed by the node to ensure traceability of the source; the processing plant end shares raw material receiving batch information, processing process parameters, quality inspection reports, finished product packaging and coding data to realize full-process traceability of the processing link; the logistics provider end is responsible for entering transportation vehicle information, real-time temperature control data, transportation route trajectory, and loading/unloading time nodes, and realizing real-time docking with the consortium chain through IoT devices to ensure the monitorability of the cold chain transportation process; the retailer end uploads receiving and acceptance records, shelf display time, and inventory turnover data, and opens traceability query permissions to consumers.

To avoid the leakage of commercial secrets, the consortium chain adopts privacy computing technology to achieve "data available but not visible": each node can only view authorized data related to its own business, which not only ensures collaboration efficiency but also maintains the commercial interests of each subject [9].

Multi-dimensional improvement from risk control to efficiency optimization: the data sharing system driven by the consortium chain, its primary value is to solve the problem of delayed risk response caused by "information silos" in the traditional supply chain. The traceability system based on the consortium chain can quickly associate full-chain data through the unique product identification, lock the source, affected processing links, transportation routes, and sales terminals within hours, accurately delineate the recall scope, and greatly reduce consumer health risks and enterprise recall costs.

In addition, the system can also bring multiple derivative values: for regulatory authorities, they can retrieve full-process supply chain data in real time to achieve "penetrating supervision" and reduce problems such as enterprise fraud and irregular operations; for enterprises, data transparency can optimize inventory management and reduce supply chain collaboration costs;

for consumers, they can obtain information such as food sources and quality inspections through convenient queries, enhance consumption trust, and promote the formation of a market mechanism of high quality and high price [10-11]. In summary, the improvement of supply chain transparency empowered by consortium chain technology is not only a “safety net” for risk control but also a core driving force for promoting the food supply chain towards efficient, credible, and sustainable development.

2.5. Challenges in technology implementation

However, there are also many challenges. First, the problem of data authenticity. Blockchain can only ensure that data cannot be tampered with after being uploaded to the chain, but the source data may be falsified. The current solution is to combine IoT devices for automatic data collection and third-party authoritative institution verification. Second, in terms of cost and standardization, the initial cost of deploying IoT devices and blockchain systems is relatively high for small and medium-sized enterprises. But this can be solved through industry collaboration: it is necessary to establish unified data format standards and jointly promote cross-enterprise on-chain collaboration. Third, in terms of the balance between privacy and permissions, there is a contradiction. Enterprises are unwilling to disclose sensitive data but need to provide verifiable information. However, we can adopt consortium chain technology, which is a blockchain architecture for sharing and synchronizing data among multiple organizations [12,13]. By using advanced privacy protection technologies such as zero-knowledge proof, we can selectively disclose necessary information under the premise of ensuring data security, thereby protecting user privacy while meeting the demand for data transparency.

Finally, in terms of user habits and cognition, the current usage rate of blockchain query functions among consumers is generally low, mainly because most users have an insufficient understanding and cognition of blockchain technology. To change this situation, we need to cultivate users’ habits through a series of marketing activities.

3. Future development directions

3.1. Technology integration

In terms of AI prediction, the large amount of data accumulated on the blockchain can be combined with artificial intelligence analysis technology to predict potential risks in the supply chain. In terms of big data optimization, in-depth analysis of on-chain consumption data can provide accurate guidance for manufacturers and inventory management. For example, optimizing production plans according to consumers’ purchasing preferences and trends, reducing inventory backlogs, and improving resource utilization efficiency [14].

3.2. Policy drive

The government plays an important role in promoting the application of blockchain technology in the field of food safety. For example, relevant standards can be formulated and promoted to regulate the development of the industry. At the same time, the government can provide financial subsidies and policy support to encourage more small and medium-sized enterprises to participate in the application of blockchain technology, improving the transparency and credibility of the entire industry.

3.3. Global network

To solve the trust problem in cross-border food trade, we will strive to establish an international consortium chain. For example, a global seafood traceability network can be built. Through multi-party participation and data sharing, every link of food from production to sales can be traced and verified, thereby enhancing the trust of global consumers [15].

4. Conclusion

Although blockchain technology has great potential, it is not a “panacea” to solve all problems. To give full play to its value, we need to combine it with other advanced technologies such as the Internet of Things and big data, and promote it comprehensively at multiple levels including policy support, industry collaboration, and user education. The core value of blockchain lies in building a multi-party trusted food ecosystem, ensuring that every link of food “from farm to table” is transparent, verifiable, and credible. In this way, we can not only enhance consumers’ sense of security but also effectively improve the operational efficiency and transparency of the entire food industry.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Liu H, Wang X, Chen W, 2021, Research on the Safe Production Mechanism of Agricultural Products Based on Blockchain Technology. Issues in Agricultural Economy, 2021(11): 66–76.

[2] Wang E, Su J, 2022, Food Supply Chain Traceability Platform Based on Blockchain. The Food Industry, 43(11): 227–230.

[3] Zhang Y, 2023, Design and Implementation of Agricultural Product Traceability and Anti-Counterfeiting System Based on IoT and Blockchain Technology, thesis, Inner Mongolia Agricultural University.

[4] Zhang M, Zhao F, Wang X, et al., 2024, Application and Research of Blockchain Technology in the Food Supply Chain. Modern Salt and Chemical Industry, 51(6): 112–114.

[5] Xu X, 2024, Research on the Traceability of Fresh Agricultural Products Based on Blockchain Technology. Investment and Entrepreneurship, 35(16): 175–178.

[6] Cao H, 2023, Research and Implementation of Grain Supply Chain Traceability System Based on the Integration of Blockchain and IoT, thesis, Henan University of Technology.

[7] Lin W, 2024, Research on the Application of Blockchain Technology in the Construction of E-Commerce Credit Systems. Business Exhibition Economy, 2024(04): 126–129.

[8] Wen X, 2025, Construction and Practice of Food Safety Traceability System Empowered by Blockchain Technology. Modern Food, 2025(6): 144–146.

[9] Wang Y, 2025, Exploration of the Collaborative Development Path of Product Traceability and Quality Monitoring in the Supermarket Supply Chain Under the New Retail Model. National Circulation Economy, 2025(13): 17–20.

[10] Zhang H, 2017, Discussion on the Development Path of China’s Agricultural Product E-Commerce Based on Blockchain. Commercial Economics Research, 2017(12): 96–98.

[11] Song Z, 2025, Blockchain Empowers Resilient Governance of Food Safety for Small and Micro Enterprises: From Traceability to Trust Reconstruction. Journal of Zhangjiakou Vocational and Technical College, 38(2): 61–63.

[12] Chen L, 2020, “Blockchain + AI + Food Traceability” Ensures the Safety of the “Vegetable Basket”: A Record of Guangzhou Building an Edible Agricultural Product Traceability Platform to Achieve Intelligent Food Safety Supervision. China Market Supervision News, March 26, 2020, A05.

[13] Liu S, 2023, Exploration and Research on Optimizing E-Commerce Agricultural Product Traceability Systems with Intelligent Technology in the Smart Agriculture Environment. Rural Economy and Science-Technology, 34(18): 242–245.

[14] Yuan J, He M, Li X, 2025, Research on the Application of Blockchain in Food Traceability. Chinese and Foreign Food Industry, 2025(11): 28–30.

[15] Zhai H, 2020, Research on the Application of Blockchain Technology in the Traceability of Agricultural Product Safety Information. Internet of Things Technology, 10(1): 90–92.