

Research of Blockchain Technology in the Traceability of Characteristic Agricultural Products

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Abstract: With the increasingly prominent problem of food safety, the quality traceability of characteristic agricultural products has become a pressing issue. This study focuses on the application of blockchain technology in the traceability of characteristic agricultural products, aiming to explore its potential and practical value in improving the efficiency and transparency of the traceability system of agricultural products. Through the combination of case analysis and model construction, a blockchain-based traceability system for characteristic agricultural products was established. The results showed that the traceability system could effectively record the whole process information of agricultural products from production and processing to sales, and greatly improve the immutability and traceability of data. Lastly, this paper also points out that the use of blockchain technology can improve the market trust in characteristic agricultural products, provide consumers with authentic and reliable product information, and provide new technical means for the quality management of agricultural products.

Keywords: Blockchain technology; Characteristic agricultural products; Traceability system; Data immutability; Market trust

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1. Introduction

With the frequent occurrence of global food safety problems, the quality and safety of characteristic agricultural products have been highly valued by consumers and regulatory agencies. As an important means of ensuring the quality and safety of agricultural products, quality traceability plays an indispensable role in increasing consumer confidence and promoting the development of the agricultural economy. However, the conventional traceability system for characteristic agricultural products suffers from various issues, including single information recording, low traceability efficiency, and susceptibility to data tampering, all of which significantly compromise the system's overall usefulness and reliability. This study is dedicated to addressing the deficiencies of the current traceability system^[1]. This study utilizes case analysis and model construction to demonstrate the feasibility and benefits of integrating blockchain technology into the traceability of characteristic agricultural products. It explores specific strategies aimed at enhancing transparency and efficiency within the

traceability system. By doing so, this research offers innovative solutions to the traceability challenges faced by characteristic agricultural products.

2. Analysis of the status quo of traceability of characteristic agricultural products

2.1. General requirements for the construction of a traceability system of characteristic agricultural products

The traceability system requires transparency, accuracy, and completeness of data. Every process of production, processing, storage, transportation, and sales of characteristic agricultural products needs to record detailed data information, which must truly and reliably reflect the condition of the product ^[2].

Real-time traceability is also an indispensable part of the traceability system. Consumers and regulators often need real-time access to relevant information on featured agricultural products to quickly respond to and deal with potential food safety problems. Blockchain technology enables the transmission and access of data in real time through its distributed ledger nature ^[3].

Traceability is the core feature of the traceability system. Every link of characteristic agricultural products, from field to table, should be traceable so that when problems are found, they can be quickly located to the responsible link ^[4]. The chain-like data structure of blockchain technology provides a complete traceability path for the whole life cycle of products

Security is a principle that the traceability system must strictly abide by. Traceability data may contain sensitive information, such as supplier information, product formula, etc., which needs to be properly protected. Blockchain technology ensures the security of each block of data with its unique encryption method. Only users with the appropriate permissions can access the specific data, preventing data leakage and unauthorized access ^[5].

User-friendliness is crucial for a traceability system. A successful traceability system should have a simple and intuitive interface and a convenient operation process so that all users can use the system without barriers ^[6]. Blockchain applications are generally accessible via web or mobile devices and can be custom-developed to meet the needs of specific user groups.

2.2. Problems existing in the current traceability system of characteristic agricultural products

Although the current traceability system of characteristic agricultural products has improved the level of food safety and consumer confidence to a certain extent, its existing problems are still prominent, especially data siloes, information tamper risk, inconvenient operation, lack of supervision, low consumer awareness and high economic cost ^[7]. These problems limit the efficiency of the traceability system and need to be solved through technological innovation and institutional improvement.

2.3. Security and credibility of traceability information

The security of traceability information of characteristic agricultural products is mainly manifested in the data input end. The data entry of each link of agricultural products from field management to production, processing, transportation, and sales usually needs to be operated manually, which poses risks like human error or intentional tampering. After recording on the blockchain, these errors or tampered information will become unchangeable ^[8]. Therefore, ensuring the accuracy and authenticity of the original data input is the primary condition to ensure the security of traceable information.

In the process of application of blockchain technology, external network attacks may occur. In addition, due to the complexity of the technology, possible vulnerabilities in the design and implementation of the system

will also become the entry point of attacks. Therefore, it is essential to ensure the network security protection of the system and continuous security audits to prevent such risks ^[9].

The consensus mechanism on which blockchain technology relies also affects the security and credibility of the system. For example, a blockchain network using a proof-of-work (PoW) consensus mechanism may be subject to a 51% attack ^[10]. For the characteristic agricultural product traceability system, choosing the appropriate consensus mechanism and ensuring the decentralization degree of the network are the keys to preventing such attacks.

The credibility aspect of blockchain technology primarily revolves around its verifiability and transparency. The immutability inherent in blockchain ensures that once data is verified and added to the blockchain, it cannot be altered, establishing a trusted source for the data. Furthermore, the transparency of the blockchain network enables all involved parties to authenticate the information's authenticity, theoretically enhancing data reliability. However, this presents new challenges—how to offer sufficient information for verification without compromising sensitive data? This necessitates striking a delicate balance between safeguarding privacy and ensuring transparency.

3. Application of blockchain technology in the traceability system of characteristic agricultural products

3.1. Introduction to blockchain technology

Blockchain technology is a distributed database technology based on decentralization, de-trust, and collective maintenance, which makes data immutable and falsifiable through a specific encryption algorithm. It allows participants in the network to exchange and transmit data securely, traceable, and tamper-free without the need for a centralized trust authority ^[11].

In the characteristic agricultural traceability system, every step of the planting, harvesting, processing, transportation, and sale of agricultural products can be recorded on a tamper-free distributed ledger. Consumers can obtain detailed traceability information of products, including production date, country of origin, inspection, and quarantine information ^[12], by scanning the two-dimensional code on the product, which ensures the authenticity, safety, and transparency of the agricultural products supply chain.

3.2. Examples of applying blockchain technology in the traceability of characteristic agricultural products

IBM Food Trust is a blockchain-based food traceability system that Walmart uses to track the mangoes it sells. Through barcode scanning, consumers gain access to comprehensive information about the mangoes' cultivation, harvesting, processing, and shipping processes. This not only enhances consumer trust but also facilitates prompt responses to food safety concerns.

Domestically, Pu'er tea producers in Yunnan Province have made it possible for consumers to trace the origin of tea leaves, production batches, and quality control standards at each link by recording production, packaging, and logistics information on the blockchain. This application not only enhances the brand value of Pu'er tea but also serves as a tool to combat counterfeit and substandard products, safeguarding consumers' rights and interests ^[13].

The application of blockchain technology in the traceability of agricultural products is multifaceted. It can not only improve the transparency of products and consumer trust but also optimize supply chain management and reduce food safety issues.

4. Practice and exploration of blockchain technology in the traceability of characteristic agricultural products

4.1. Feasibility of integrating blockchain technology into the traceability of agricultural products

The feasibility analysis of the integration of blockchain technology into the traceability of agricultural products needs to be comprehensively considered from the aspects of technology maturity, operation implementation, economic cost, and social effect. From the perspective of technology maturity, blockchain technology has undergone several years of development. From the initial application of Bitcoin to the smart contract of Ethereum, the technology has been gradually improved and adopted by many industries.

(1) Operational implementation

The traceability of characteristic agricultural products requires the cooperation of all parties, including farms, transportation companies, processing plants, and retailers. Blockchain technology automates the execution of agreements through smart contracts, providing a shared but immutable data platform for different participants. The record of each transaction requires joint verification by network participants, which enhances the transparency and traceability of the entire process of agricultural products from field to table.

(2) Economic costs

Studies have shown that blockchain technology can reduce redundant steps in the supply chain and improve operational efficiency, thereby reducing overall logistics costs.

(3) Social effects

The introduction of blockchain technology can provide more transparent information on food production, processing, and distribution, which plays a positive role in improving the brand image of local characteristic agricultural products. When there are quality problems in agricultural products, blockchain technology can also quickly locate the problem link and effectively control the spread of risks.

4.2. Technical challenges and countermeasures faced by blockchain technology in the traceability of characteristic agricultural products

Although the application of blockchain technology in the traceability of characteristic agricultural products has many advantages, there are still a series of technical challenges in the actual promotion process.

(1) The capacity and cost of data storage.

Given that the production, processing, and distribution processes of characteristic agricultural products generate substantial amounts of non-tamperable and traceable data, the maintenance costs of blockchain can significantly escalate. To address this challenge, sidechain or sharding technology can be employed to mitigate storage issues. Sidechain technology enables the delegation of specific data processing and storage tasks to auxiliary chains external to the main blockchain ^[14].

(2) Processing speed and scalability impediments.

Traditional blockchain technology has a long transaction confirmation time and limited throughput. To this end, the consensus mechanism of blockchain can be optimized. The optimization measures include improving the proof-of-work (PoW) mechanism, proof-of-stake (PoS) mechanism, and the efficiency of the Byzantine fault tolerance algorithm, which in turn improves the transaction processing speed and network scalability ^[15].

(3) The security challenges of smart contracts.

Once a smart contract is deployed on the blockchain, its code cannot be changed, which requires that

the smart contract must be written with precision. To improve the security of smart contracts, formal verification methods can be used to prove the correctness of smart contracts, and a series of tools and frameworks can be developed to help developers detect and fix vulnerabilities in smart contracts.

(4) User privacy protection.

The transparent nature of blockchain may expose users' private information. To solve this problem, zero-knowledge proof, mixed coin technology, homomorphic encryption, and so on can be used. The application of these privacy protection techniques can verify the validity of transactions without disclosing the privacy of users.

(5) Cross-chain interoperability.

Featured agricultural products may involve the information recording and sharing of different blockchain platforms. Therefore, it is particularly important to achieve interoperability between different blockchains. To solve this problem, some cross-chain protocols and frameworks, such as inter-chain communication (IBC) protocol and cross-chain bridge technology, can be explored to achieve seamless connection and information transfer between different blockchain platforms.

5. Conclusion

The results of this study show that blockchain technology can significantly improve the efficiency and transparency of the agricultural product traceability system, ensuring the immutability and traceability of data. The introduction of this new technology not only enhances the market's trust in the characteristic agricultural products but also provides consumers with reliable product information from the source, which is of great practical significance for improving product quality control and optimizing supply chain management. This study also has certain limitations, such as insufficient exploration of the integration of blockchain technology with the existing traceability system of agricultural products. Future research should focus on the cost reduction of blockchain technology in practical applications. Through continuous technological innovation and system improvement, blockchain technology is expected to become one of the key technologies to improve the competitiveness of Chinese characteristic agricultural products.

Disclosure statement

The author declares no conflict of interest.

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