Research Review of Agricultural Product Traceability System Based on Blockchain Technology

ABSTRACT: With the frequent occurrence of domestic agricultural product safety accidents in China, consumers' trust in the quality and supply chain of agricultural products is gradually declining. Traceability, as a production control system that can connect all links of product circulation and manage undirected tracking of products, is of great significance to guarantee the quality and safety of products. In the traditional traceability system, there are problems of asymmetry, inaccuracy, non-transparency and insecurity of information. Blockchain can provide powerful technical support for the construction of agricultural products traceability system by virtue of decentralization, transparency and openness, non-tamperability and distributed storage. Applying blockchain technology to agricultural products traceability can effectively protect the rights and interests of all members of the agricultural products supply chain and the general consumers. Based on the analysis of the concept and main features of blockchain, this paper summarizes the research and application progress of blockchain-based traceability system at home and abroad in recent years by studying the traceability mechanism of agricultural products. The advantages and challenges of the implementation of blockchain-based agricultural products traceability system are elaborated. It is hoped that this paper can provide useful references for the research and establishment of blockchain agricultural products traceability system.

KEYWORDS: *blockchain technology; agricultural product traceability; traceability system; Internet of Things technology; distributed storage*

1. INTRODUCTION

China is a large agricultural country. In recent years, with the development of agricultural information technology and the improvement of people's living standard, the quality and safety of agricultural products have been widely concerned by the state. Due to the large scale of agricultural production and the difficulty of supervision, the quality of agricultural products has been a continuous problem, leading to a crisis of consumer trust [1]. The process of agricultural products from planting to becoming commodities for sale has undergone a large span of time and space, and various quality problems are prone to occur in various aspects, mainly in the following aspects: First, repeated manual testing. As the information of agricultural products planting, processing, logistics and sales are isolated from each other, it is difficult for the current traceability system to ensure the quality of agricultural products, and the problem of repeated testing of agricultural products quality is more common; secondly, information silos. The seller needs to test the information of agricultural products for each processing link, and some information does not appear in other links but is blocked in this link; thirdly, it is difficult to supervise. When supervising the quality of agricultural products, if there is no trust in the safety and quality testing of a certain link, it will lead to repeated testing of information and no sharing of information, which will increase the cost of supervision [2]. At the same time, once an agricultural safety accident occurs, the relevant information can easily be maliciously altered by the person responsible, making it difficult to pursue responsibility for the accident and difficult to obtain evidence.

The supply chain of agricultural products has the characteristics of long life cycle, complex links, multiple sources of information, and heterogeneity. The key to doing a good job in the quality and safety of agricultural products is to pay attention to the effective monitoring of the source data of agricultural products, and at the same time, all production links must be effectively combined [3]. The safety of agricultural products is essentially a problem of trust between buyers and sellers in the market. Asymmetric production information and opaque information can easily cause consumers to panic about products. However, the traditional traceability system built by enterprises today has the disadvantages of being centralized and easily tampered with internally [4]. Therefore, this is a kind of "self-certification" behavior. The centralized data storage method is easy to be deleted and changed, and the traceability system is naturally untrustworthy.

As an emerging Internet technology, blockchain adopts core technologies such as distributed data storage, consensus mechanism, smart contract and cryptographic algorithm at the bottom. The data on blockchain has the characteristics of tamper-proof, open and transparent, and permanent storage. After the data is confirmed by consensus, it is distributed in each node, which can realize safe and reliable data backup. Relying on blockchain technology, the IOT data and agricultural management data related to agricultural production can be persistently stored in a distributed and multi-party maintenance form, establishing a trust storage model for agricultural big data and laying the foundation for the sustainable development of future smart agriculture [5, 6]. The agricultural traceability system with blockchain technology infrastructure is a trustworthy and immutable record management system, which enables various resources to be recorded, tracked and used from the source, and ensures the integrity of records and services.

At present, most of the traceability systems based on blockchain technology are still in the stage of theoretical verification and experimental pilot. To truly bring "blockchain + traceability" into people's lives, efforts from various aspects such as market economy, national policies and enterprise innovation are still needed. In addition, there are still some problems to be solved in the traceability system of agricultural products based on blockchain technology. For example, although blockchain technology can guarantee the authenticity of data on the chain, the risk of tampering with the physical level of front-end collection is still high. Therefore, how to carry out data anti-counterfeiting more effectively is an important research topic. Through the literature retrieval method, this paper comprehensively analyzes the research progress of blockchain technology in the traceability of agricultural products at home and abroad. On the basis of analyzing the concepts of traceability and traceability system, it expounds the advantages and challenges of implementing the blockchain-based agricultural product traceability system. It is expected to provide useful reference and reference for the research and establishment of the blockchain agricultural product traceability system.

2. TRACEABILITY OF AGRICULTURAL PRODUCTS

2.1. Traceability of traditional agricultural products

Traceability refers to the activities of tracking and tracing the history, application or location of an object through records or identification. The traceability system refers to the integration of modern information management and access to data related to the product traceability process based on traceability codes, file records, related software and hardware equipment and communication networks. The agricultural product traceability system can record and store the agricultural product data information in the supply chain from production to sales [7]. Once the agricultural product quality and safety problem occurs, the system can quickly trace the product source, locate the responsible subject, and promptly recall the problematic batch of products. At present, the supply chain traceability of agricultural products focuses on the use of radio frequency identification, two-dimensional code, wireless sensor networks and other Internet of Things technologies to track and record the data of agricultural products in the production, processing, transportation, sales and other aspects to achieve "from farm to table" supervision of the whole process [8]. Table.1 lists the typical traceability systems established at home and abroad in the field of large fresh agricultural products such as aquatic products, agricultural products, fruits and vegetables [9, 10].

Table .1 Agricultural products traditional traceability system

Traceability Subjects	Traceability links	Data Acquisition	Data Storage	Data Supervision	Data Identification
Fishery products [27]	Processing link, transportation link, merchant and quality inspection link	Enterprise entry	Traceability center database	Regulatory authorities	QR codes and barcodes
Vegetables [28]	Production management link, data upload link, Coding link, circulation link	Handheld computer-controlled acquisition, Manual entry, database import	Enterprise database and traceability center, database	Corporate Regulatory Authority	QR code
Navel oranges [29]	Orchard information management link, processing link, storage link, transportation link, marketing link	Enterprise entry	Traceability center database	Enterprise supervision department	RFID barcode
Agricultural products [30]	Planting process, harvesting process, processing process, marketing process	Terminal equipment collection	Enterprise database, product database, production file database	Regulatory department	QR code

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It can be seen that the traditional agricultural product traceability system has problems such as manual intervention in data entry, relying on third-party agencies to supervise data security, and data storage in the local database of the enterprise, which can easily lead to tampering and leakage crises in the process of data transmission and sharing.

2.2. Origin of Agricultural Product Traceability System

The earliest traceability system for agricultural products originated in Europe in the 1970s, when a serious outbreak of mad cow disease occurred in Europe, and European countries began to trace the origin of livestock agricultural products such as beef and mutton. After suffering from mad cow disease again in 1997, the European Union established a traceability system for cattle and beef and beef products. By labeling cattle ears and issuing animal passports, the system ensures that consumers can track the entire process information of the cattle from raising to slaughtering to processing and sales through the traceability system. At present, the EU has established a traceability system for livestock, poultry and their meat products, genetically modified products and feed [11, 12].

In Japan, the "food traceability system" has been promoted since 2001, and most supermarkets have installed product traceability terminals to basically achieve traceability in the food retail business. In 2003, Japan began to implement traceability of beef products. In 2005, the Japan Agricultural Cooperative Organization (referred to as the Agricultural Cooperative Association) required that the agricultural products listed and circulated through the Agricultural Cooperative Association must be traceable [9-10]. In 2008, Japan announced its intention to establish a traceability system for rice [14].

At the beginning of the 21st century, the United States began to build a traceability system at the national strategic level and established the National Animal Identification System (NAIS). Australia has also built the National Livestock Certification System (NLIS), which issues a unique "ID card" to each cow through RFID technology to realize the whole process of data collection for breeding. India uses GrapeNet to establish a traceability platform to ensure the safety and quality of exported grapes.

China started late in traceability of agricultural products, but has been making progress. In 2004, the former Ministry of Agriculture took the lead in Beijing and Hebei to start the pilot traceability system and implement the "pilot project of vegetable product quality traceability system into Beijing" [12]. In 2008, the state took the initiative to establish and improve the identification of agricultural products, and establish and implement a traceability system for agricultural products. The traceability system of safety. In addition, the national vegetable quality and safety traceability system is also being constructed and piloted. In 2017, the national agricultural product quality and safety traceability management information platform was officially launched, and pilot projects were first launched in Sichuan, Guangdong, Shandong and other places [15].

3. BLOCKCHAIN AND AGRICULTURAL PRODUCT TRACEABILITY

3.1. Blockchain

3.1.1 Introduction to Blockchain

Blockchain technology originated from Bitcoin. In 2008, a user who called himself "Satoshi Nakamoto" published the article "Bitcoin: A Peer-to-Peer Electronic Cash System", which proposed the idea of Bitcoin. With the popularity of Bitcoin, blockchain has gradually entered the public eye as the underlying technology of Bitcoin. Blockchain is a continuously growing distributed database maintained by multiple parties. It establishes trust relationships based on distributed networks, cryptography and consensus mechanisms, and builds the Internet of Value through smart contracts [16]. The essence of blockchain is a shared ledger, which solves the problems of subject collaboration, information miscommunication, and lack of supervision by developing a distributed platform. Based on the computing, storage and network sharing model of the whole network nodes, it provides big data sharing and evidence preservation. Through zero-knowledge proof and secure multi-party computation, data can be verified without disclosure [17]. All nodes in the blockchain network architecture interconnect and communicate peer-to-peer to jointly query, record and maintain ledger data, break information silos, extend the boundaries of networked operation, and realize the decentralization of blockchain network.

The block structure consists of block header and block body (see Fige.1). The block header stores the hash value of the previous block, enabling reliable traceability of data on the chain. Modifying the data of any block in the long chain will invalidate the hash of this block, which will cause the chain to be broken, and it will take huge computing power to recalculate the hash value of this block and all subsequent blocks [18, 19]. The Merkle root stored in the block header can quickly verify the tampering of transaction data. The block body contains all the verified traceability records of the value exchange during the block creation process. The specific traceability record fields vary from node to node. The above mechanism ensures that the block data cannot be tampered with once it is verified and written.

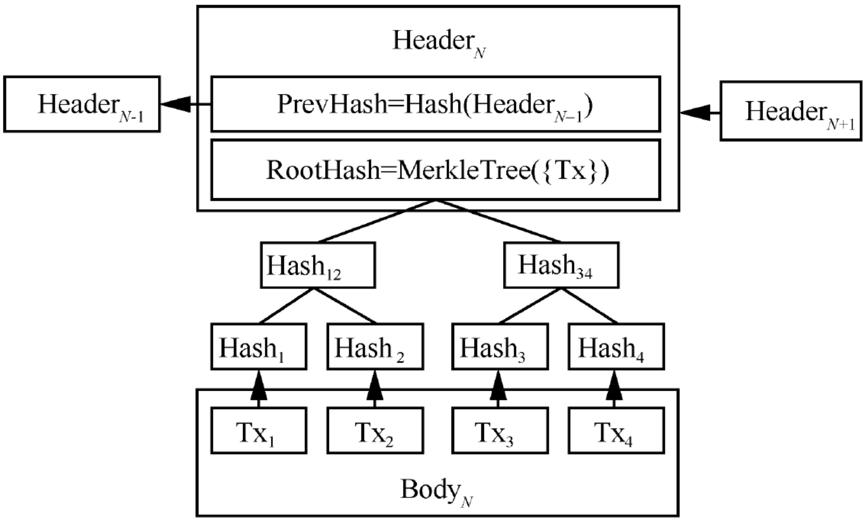

Fig.1 Schematic diagram of the basic blockchain structure

3. 1.2 Blockchain Classification

According to the way of node participation, blockchain can be divided into public blockchain, private blockchain and Consortium blockchain. According to the participation permissions of nodes, blockchain can be divided into permissioned blockchain and permissionless blockchain.

Table .2 Type of blockchain

Chain Type	Public Chain	Private Chain	Alliance Chain
Node Participants	Everyone	Individuals or organizations	Affiliate
Bookkeeping Rights	Seeking bookkeeping rights based on consensus mechanisms	Customized bookkeeping rights within an individual or organization	Bookkeeping after consultation and confirmation by federation members
Read and write permissions	No restrictions on read and write to participating nodes	Write access is controlled internally, read access is open on demand	Nodes can read and write with authorization
Motivational approach	Required	Not required	Customize the incentive method according to business needs
Network Characteristics	Decentralization, large network scale, low throughput	Weak centralization, small network scale, high throughput	Multi-centralization, small network scale, high throughput
Data Storage	All Nodes	Weakly Centralized Institutional Nodes	Polycentric Nodes
Applications	Open transaction data, mainly used in the field of virtual currency Application	Transaction data is not public, mainly used in auditing and banking Fields	Channel isolated transaction data, mainly used in cross-industry and cross-ecological collaboration

	Areas		

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3. 1.3 Features of Blockchain

Blockchain has the characteristics of decentralization, openness, independence, security, and anonymity. (1) Decentralization. The blockchain does not rely on third-party managers and hardware, and does not have a central server. Through distributed computing and storage, each node realizes self-validation, transmission and management of data. (2) Openness. The blockchain technology is open source, except that the private information of the transaction is kept secret, the data in the blockchain is open to everyone, and everyone can enter the blockchain through the public interface for query and development. (3) Security. As long as 51% of all nodes are not mastered, the data cannot be tampered with casually, which makes the blockchain avoid malicious tampering. (4) Anonymity. The identity information of any node does not need to be disclosed and verified, and data transfer can be sent anonymously. (5) Traceability. Upload the information to each block in the blockchain, each block has the hash value of the previous block, and only the correct hash block can be identified on the chain, which ensures the traceability of the information [20].

3. 1.4 Blockchain traceability technology

Due to its own characteristics, blockchain has great advantages over traditional traceability methods (Table.3). Compared with the traditional traceability method, the data collection work in the front-end of the traceability method based on blockchain technology is not much different from the traditional method, but the big difference lies in the back-end. Blockchain technology can provide new traceability tools to facilitate consumers' inquiry of agricultural product safety information. The blockchain has the characteristics of decentralization, each node can share data in real time through the chain, and all nodes must also fulfill the obligation to jointly maintain the reliability of data [21-24].

Table.3 Differences between blockchain traceability and traditional traceability

Distinction	Traditional Traceability	Blockchain Traceability
Front End	Use various sensors, information collection terminals and other equipment to complete the collection of data	Not much different from the traditional way
Back end	Traceability based on anti-counterfeiting codes made by merchants, which are easily imitated	Blockchain provides new tools for traceability business, and information can be queried through RFID chips or QR codes and bar codes
Information Tampering	Centralized storage model makes data vulnerable to tampering by authorized parties	Digital entry reduces manual involvement and protects data from tampering
Security	Centralized storage model, data is vulnerable to attack	Decentralized storage model, any one node is damaged will not affect the normal operation of the whole system
Transparency	Only the results, not the process, the data is not transparent and real	The data is automatically recorded throughout the process from entry, modification to finalization, guaranteeing High transparency and authenticity of data
Autonomy	Highly dependent on central institutions, poor autonomy	Highly autonomous with algorithms created based on consensus mechanisms to remove human interference

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3.2. Research progress of blockchain traceability system

At present, scholars and institutions at home and abroad apply blockchain in agricultural products traceability, and blockchain technology has been integrated with Internet of Things, cloud computing and cloud storage to make significant breakthroughs in agricultural products supply chain, agricultural products transportation, data management and intelligent agriculture, which can improve efficiency and reduce logistics to a certain extent.

3.2.1 Combining blockchain technology with IoT technology

IoT technology has been quite mature after years of development. The combination of IoT technology and blockchain traceability system will make the traceability technology more intelligent and convenient, and at the same time, IoT technology will make the information more reliable, so the combination of IoT technology and blockchain traceability technology is the development trend of traceability technology. George et al. combined IoT technology and blockchain technology to achieve traceability for pig breeding, processing, and retailing, using various sensors to collect information on pig growth, slaughter, and processing, and finally uploading the data to the blockchain to complete traceability [25]. Ali et al. proposed a data service center combining federated chain and smart contracts with IoT traceability services [26]. Bordel et al. combined RFID electronic tagging technology and blockchain technology to design a food safety traceability system [27]. Mingjia Li et al. applied blockchain technology to the database and communication layers in the traditional traceability system and designed a method to make the data in the traditional traceability system better accessible to the blockchain [28]. Shi, Liang et al. used the features of distributed storage and node resource sharing of blockchain to achieve forward and reverse bi-directional tracking of traceability links [29]. Stamatelis and others designed electronic medical records using the blockchain distributed ledger and identity anonymity, which effectively ensured the authenticity of information and the privacy of patients [30]. Xiyong Zhu et al. used hazard analysis and critical control point system (HACCP) to analyze the hazards of each step of garment production and finally used blockchain technology to achieve the traceability of the cause of hazards [31].

In the blockchain agricultural traceability system, RFID tags, WSN (Wireless sensor network), BDS (BeiDou navigation satellite system) and other IoT technologies are used to identify production information, processing information, transportation information and sales information. According to a certain format sent to the data center for "one thing, one code" identification, the collected data will be automatically uploaded to the blockchain for storage, the use of blockchain technology to ensure the privacy protection and non-tampering data [32]. Consumers or regulatory authorities can query the data information of commodity circulation through the traceability code to achieve "one thing, one code" authentic traceability. Table.4 lists some of the applications of “blockchain + IoT” model in agricultural product traceability.

Tab.4 Traceability based on blockchain and IoT

Literature	IoT Devices	Introduction
Literature [33]	RFID	Add RFID tags to products to save product information in the whole process of production, processing, transportation and sales, and store product information cipher text in the alliance chain for data verification.
Literature [34]	RFID	An international commercial food traceability system based on Ethereum, smart contracts and RFID tags is proposed. The RFID tags are used to record food identifiers, and the unique identifiers of food in the area are read by wireless communication devices and sent to the data center for on-chain processing.
Literature [35]	RFID	Establish a blockchain ledger in the production, processing, warehousing, transportation, and sales of RFID-labeled items, and establish a chain path for the traceability of RFID big data.

Literature [36]	Lora	Reduce manual intervention data through Lora equipment; block chain verification of stored data; smart contract script to achieve automatic alarm; to achieve a trusted, self-organized and open and transparent smart agricultural product traceability system.
Literature [37]	IoT Sensors	Implement integrated IoT sensor devices based on Ethereum or Hyperledger sawtooth, record valuable information in the agricultural supply chain through IoT devices and directly upload the data to the chain for certification.

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A large number of studies have shown that the traceability system of agricultural products based on blockchain and IoT can improve the efficiency and reduce the logistics cost to a certain extent. "Blockchain + Internet of Things" realizes the risk-free, leverage-free and high-efficiency transfer of credit between things, and realizes the unification of capital flow, logistics and information flow on the chain [38]. The application of IoT ensures the trustworthiness of everything, realizes the mapping between the physical world and the digital world, and ensures the authenticity and integrity of the information on the chain, and further helps the traceability development of the smart supply chain.

3.2.2 Improving smart contracts to establish traceability system

Smart contracts in blockchain technology can also be useful for traceability systems. Casino et al. used a combination of smart contracts and HACCP to design a traceability system for the whole process of yogurt production, processing and sales [39]. Mohamed et al. developed a smart contract model for IoT information traceability, which is very inspiring for the design of agricultural traceability [40]. Yan Ge et al. extracted the data structure using HACCP specification to provide support for the upper traceability business layer, and finally invoked a smart contract to receive data and pack the data into blocks to realize oyster quality monitoring [41].

3.2.3 Improving Blockchain Technology to Enhance the Convenience of Traceability Systems

The development and promotion of blockchain traceability system should first improve the service quality of blockchain technology. Yin et al. proposed a collaborative training model based on blockchain technology, which uses the decentralized accounting technology of blockchain to solve the trust problem between different participants [42]. Wang Hongmei et al. used a BCS (blockchain service) distributed ledger cloud platform to make the traceability system more reliable [36]. For the situation that the fully decentralized public chain cannot meet the demand of real-time business in terms of its timeliness and response speed when executing smart contracts, the private chain and the existing distributed structure and cloud platform architecture are not applicable to many participants at times. Jiying et al. designed a consortium chain with government regulators as the core, which can make the traceability system more convenient and efficient [27].

3.2.4 Strengthen the security supervision of blockchain technology to ensure the authenticity of data

Blockchain traceability system is of great significance to ensure people's interests. It is necessary to improve the security of blockchain technology and strengthen the supervision of enterprise private chains as well as the legal awareness of relevant enterprises and personnel. Zhou Zhengqiang et al. proposed a scheme for secure sharing of medical data based on the federated chain, storing metadata with the federated chain, combining smart contracts and ciphertext encryption technology, and designing a secure protocol for data sharing [43]. Zheng et al. proposed a blockchain-based decentralized data transaction system for the big data security issues that have emerged in recent years, which has important implications for data security in blockchain traceability systems [44]. Yu, Heilong et al. designed and implemented the information traceability system of the whole rice supply chain based on the Hyperledger Fabric platform. Before the supply chain traceability privacy data is uploaded to the blockchain network, it is symmetrically encrypted using ciperblock chaining (CBC). The key is encrypted using elliptic curve cryptography (ECC) and then written to the blockchain network. The ciphertext of the encrypted privacy data is stored in the blockchain network, and authorized nodes use their private keys to view the traceable privacy data on the blockchain to share the privacy data in the blockchain network [45].

3.3. Application progress of agricultural product traceability system based on blockchain technology

At present, domestic and foreign scholars and institutions have applied blockchain to the traceability of agricultural products, and have made major breakthroughs in agricultural product supply chains, agricultural product transportation, data management, and intelligent agriculture. In the application of the blockchain traceability system, many foreign companies have tried to apply the blockchain traceability system to business [42]. In June 2016, Walmart Department Store Co., Ltd. (“Walmart” for short) began to use the blockchain traceability system to test and run in the U.S. mango market. Due to the serious food safety accident in Walmart in 2018, the traditional traceability method cannot completely solve the problem. In 2019, all Walmart supermarkets began to use the blockchain traceability system. In addition, Wal-Mart and International Business Machines Corporation ("IBM") jointly established a food trust system (food trust) to track mango and pork products. It is built on the Hyperledger Fabric platform, and all data is stored on a blockchain ledger, accessible throughout the supply chain from producers to consumers. Without the Food Trust system, the process of identifying the source of mangoes may have required tracking for 7 days, while with the Food Trust system it only takes about 2.2 seconds [46].

Finland applied the blockchain traceability system to the container transportation project for the first time. Provenance is a company that promotes a blockchain-based traceability system for fish products. Through the company's application, each fish product has a unique label that includes information on the packaging, shipping and storage conditions of the fish product. In 2017, Zhongan Technology Service Co., Ltd. used the blockchain traceability system to combine with chicken raising, and put on a unique label from the birth of the chick. Using sensor technology, the daily activities of chickens are monitored in real time, and the air and soil and water indicators of the chicken house are detected until the chickens are sent to the slaughterhouse; the information of each step is uploaded to the blockchain to save [47]. In December 2017, the 1st food safety blockchain consortium was established in China. In 2017, Ant Financial, a subsidiary of Alibaba (China) Network Technology Co., Ltd., launched a blockchain traceability application [43]. Huawei Technologies Co., Ltd. launched the "Agricultural Fertile Soil Cloud Platform", which has created a multi-link blockchain traceability system including seeds, planting, agricultural product processing, and edible flavors [48].

Table.5 Traceability applications of agricultural products based on different blockchain platforms

Literature	Description	Platform	Effect
Literature [44]	Pork and mango	Hyperledger Fabric	Mango traceability time shortened from 7 d to 2.2 s
Literature [45]	Grains	Hyperledger Fabric	About 15% increase in value of GMO-free soybeans
Literature [46]	Fresh food	Hyperledger Fabric	Optimised operation, saving 850 working hours
Literature [47]	Eggs	Hyperledger Sawtooth	Improve product traceability from farm to fork
Literature [48]	Agricultural products	Hyperledger Sawtooth /Ethereum	Reduce network latency and improve reliability
Literature [49]	Food	Ethereum	The average information query response time is around 2 ms, while the data volume and query times on the chain are 1 GB and 1 000 times/s, respectively.
Literature [50]	Agricultural products	Ethereum	Data accessibility, tamper resistance and resistance to man-in-the-middle attacks
Literature [51]	Imported Products	Ethereum	The average block interval is 13.3 s, the maximum block interval is up to 58 s, and the minimum block interval is 1 s

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4. ADVANTAGES AND CHALLENGES OF AGRICULTURAL PRODUCT TRACEABILITY SYSTEM BASED ON BLOCKCHAIN TECHNOLOGY

4.1. Advantages

Blockchain has a profound impact on the research and practice of agricultural product traceability. When combined with IoT devices, it can overcome problems with information security and transparency.

4.1.1 Information security

Information storage is more reliable in blockchain-based traceability systems due to the consensus mechanism, which enhances data integrity and security [50]. In addition, it provides a high degree of invariance and information integrity, and it improves the efficiency of transactions when connected to Internet of Things (IoT) devices. [51]

4.1.2 Technical Advantages

Information is stored in multiple ledger databases through cryptographic operations and is difficult to be attacked. The consensus mechanism ensures that information cannot be tampered with when all participants reach consensus in the traceability process [52].

4.1.3 Ensure Secure Supply Chain Collaboration

Interoperability and integration of business processes across organizations perform tasks with distributed services. Blockchain tracks tamper-free historical information throughout the traceability chain, enhancing trust and collaboration among supply chain partners [53, 54].

4.1.4 Reducing product waste and economic loss

Since blockchain technology can trace the details of the product at each stage, thus making the information about the product available at all stages and avoiding the waste of the product due to information asymmetry [55].

4.2. Challenges

Blockchain technology applied to traceability of agricultural products can revolutionize the existing traceability situation, but still faces multiple challenges. Table.2 lists the current issues that still need to be addressed.

Table.6 Current Challenges of Blockchain Traceability

The field	Challenges	Problem Description

technical field	Vulnerabilities in smart contracts	Since the information of the blockchain cannot be tampered with, when there is a problem with the smart contract, the modification will be very troublesome [43]
	Combining with IoT Technology	The Internet of Things technology is used as the front-end collection link, the data is easy to be faked, and it is difficult to change after uploading [44]
	data security issues	51% of the computing mechanism of blockchain technology is not absolutely secure [45]
Infrastructure field	Inadequate infrastructure	Most of the links lack effective data collection and uploading mechanisms, and lack easy and reliable public chain or federated chain service facilities [46, 47]
Implementation field	poor interoperability	The interaction of each link in the business process is poor, and the degree of backtracking between the links is low [48]
	Lack of standardization and flexibility	A simple and flexible standard system needs to be developed [49]
Social regulation field	Lack of a mature legal system	There is no matching legal system to regulate blockchain [50]
	Regulatory issues	To ensure that regulators can protect the interests and privacy of all parties [51]
System Performance field	Node interaction	Blockchain nodes require frequent and large amounts of data interaction, which current IoT technologies cannot meet [52]
	energy consumption problem	A complete blockchain system consumes huge computer and power resources [53]
	Storing data	Sustainable traceability systems need to store massive amounts of data [54]

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5. CONCLUSION

With the explosive growth of the number of IoT devices and the increasing progress of blockchain technology, the combination of IoT and blockchain technology has become a hot spot in the current research of agricultural product traceability. In the IoT ecological environment, blockchain provides a distributed decentralized trust platform to solve the problems of security, trust and privacy in IoT, and gives new characteristics such as decentralized, traceable and non-tamperable IoT data. Applying blockchain technology to the agricultural product quality traceability system makes the supply chain transparent, increases trust among participants, realizes the traceability of the whole process of agricultural product production, and safeguards public consumption and food safety.

Future research can adapt and evaluate the operational framework, design architecture, and analysis process of blockchain-based traceability from several perspectives, with special attention to the hardware deployment, storage capacity, transaction speed, and overall performance of blockchain-based agricultural traceability systems. Specifically, it can be carried out from the following aspects:

(1) Ensure that the speed of blockchain transactions matches the massive amount of data that needs to be processed in agriculture. The sensors in agricultural IoT collect a large amount of data in the whole supply chain process leading to more and more data stored by each node subject in the blockchain, which increases the burden of storage and calculation. As more and more nodes join, the transaction volume becomes larger and larger, and new users need to synchronize the existing block information after joining, and the task can be performed only after the synchronization is completed. Due to the slow processing speed of transactions in the blockchain itself, it leads to the reduced practicality in the actual large-scale use.

(2) Guarantee the reliability of the data on the chain of the Internet of Things. Blockchain can guarantee that the data in the chain is immutable, but how to ensure the authenticity of the data before it is chained is the focus of future research.

(3) Optimize the integration framework of blockchain and IoT to improve its scalability and flexibility. The heterogeneity of data is the core problem faced by IoT. Blockchain technology can solve many problems in IoT, but blockchain itself is not specially designed for IoT. How to combine blockchain technology with IoT in an efficient and secure way is a problem worth studying.

DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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