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Food Information Traceability in the Supply Chain of a Food Ordering Platform Based on Big Data and the Internet of Things

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ABSTRACT. *Online food ordering gains popularity in the information age. Accordingly, tracing food information has emerged as a major demand for businesses and consumers. Manual data collection is often used in traditional research. Each link is relatively isolated, resulting in recording incomplete and asymmetric information, which often increases the difficulty of tracing food information and restricts the effectiveness of information. This article aims to enhance the real-time integration and transparency of supply chain information through sensors and blockchain technology, thereby ensuring food safety and quality. Internet of Things (IoT) technologies such as radio frequency identification tags, sensors, and Global Positioning System devices are used for data collection. Wireless network technologies such as long range radio and narrow band IoT can be utilized for data transmission, and Hadoop distributed file system and Cassandra database can be used for data storage and management. The Hyperledger Fabric blockchain platform, combined with Solidity smart contracts and advanced encryption standard encryption algorithm, enables automatic recording, verification, and secure storage of data, ultimately achieving real-time query and display of food traceability information. Results show that the missing data rate is only 5% among 200 samples, and the data latency remains at a relatively low level even with a large number of experimental samples. This article successfully improves the real-time integration and transparency of supply chain information by combining sensors and blockchain technology, effectively guaranteeing food safety and quality.*
Keywords: Food Traceability; Blockchain Technology; Internet of Things; Supply Chain Management; Real-time Data

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1. **Introduction.** In recent years, frequent food safety accidents have attracted high global attention to the issue of fresh food safety. Food safety issues often arise from inadequate management during planting, breeding, processing, production, storage, transportation, and sales [1, 2]. To reduce the harm caused by food safety issues, relevant regulatory authorities usually immediately stop the sale of the batch of food and implement information tracing. With the improvement of social and economic level and quality of life, the Internet of Things (IoT) develops rapidly. People's requirements for food ordered online are becoming stricter, and the demand for open and transparent food information is growing [3, 4]. However, in reality, corresponding to this high demand

are scarce food information and almost invisible transaction logistics. This contrast constantly deepens customers' anxiety while affecting the reputation and promotion of businesses and food manufacturers. Traditional food safety traceability systems often use manual data collection, resulting in incomplete and asymmetric information at various stages, which increases the difficulty of traceability. Big data (BD) and IoT technology, with their excellent data collection and processing capabilities, have strong advantages and feasibility in the field of food information traceability. They can effectively improve the real-time integration and transparency of supply chain information, ensuring food safety and quality.

The main purpose of this study is to improve the real-time integration and transparency of food information in the supply chain of the ordering platform by integrating sensors and blockchain technology, ensuring food safety and quality. Multiple devices can be used for data collection, wireless network technology is used for data transmission, distributed file systems and databases are used for data storage and management, and blockchain platforms are combined with smart contracts and encryption algorithms to achieve secure data storage. The method studied in this article has a low data loss rate in food information tracing and can maintain low transmission latency even when dealing with large sample data. Real-time query and display of food traceability information are achieved, remarkably improving the information transparency and food safety assurance capabilities of the supply chain, providing strong support for the supply chain management (SCM) of online ordering platforms.

2. **Related Work.** In recent years, food information tracing has become an important means of ensuring food safety, and many studies have focused on this topic. Qian C et al. explored the application of artificial intelligence technology in the field of food safety, including risk prediction, supply chain optimization, public health system improvement, and pathogen detection [5]. Rana, Roberto Leonardo, and others have screened 10 years of academic articles through detailed criteria and keywords, and they found that blockchain technology can contribute to the sustainability of agricultural food production but still faces many challenges [6]. Yu, Zhilong, and others reviewed an intelligent food traceability system, which integrates portable detection devices, intelligent packaging sensors, and data-driven whole genome sequencing technology to enhance global food supply chain security [7]. Yuan, Chunlin et al. constructed a research framework for the relationship between food traceability systems and consumer perceived value and purchase intention based on participation and customer value theory, and they explored the moderating role of consumers' professional knowledge in this relationship [8]. Through questionnaire surveys and structural equation modeling analysis, the influence of food traceability system quality on consumer perceived value and its promoting effect on purchase intention were revealed, providing theoretical basis and management insights for food traceability system marketing strategies. Balamurugan, S et al. proposed a health electronic food network model based on blockchain technology and the IoT to address safety, quality, and traceability issues of food products [9]. These studies indicate that although food traceability systems have made substantial progress, they still face challenges in terms of technology integration and user engagement, thus requiring further optimization and improvement.

To achieve effective food information traceability, researchers have proposed various techniques and methods. Mondal, Saikat, and others proposed a transparent food supply chain architecture based on the integration of blockchain and the IoT. This system uses a "proof of object" authentication protocol similar to cryptocurrency, combined with RFID sensors for real-time monitoring of product quality. It also builds a tamper-proof digital food information database [10]. Bhat, Showkat Ahmad proposed an agricultural

SCM model based on blockchain and the IoT, aiming to address transparency, storage, scalability, interoperability, security, and privacy issues in the current agricultural supply chain [11]. By integrating blockchain and IoT technologies, this model optimizes the supply chain process and improves response speed. Casino, Fran, and others proposed a distributed, trustless, and secure food supply chain traceability architecture, which they tested and validated through the development of smart contracts and local private blockchain. He not only demonstrated the feasibility of this method in tracing cases in dairy companies but the noteworthy achievements of blockchain technology in improving supply chain transparency and management efficiency [12]. Lei, Moyixi, and others studied food traceability methods based on the IoT, artificial intelligence, privacy protection, and blockchain technology. They systematically reviewed the application of privacy protection technology in food traceability and analyzed the data flow and technical security requirements at each stage [13]. They revealed the advantages of privacy protection integration and discussed the limitations of current food traceability technology, providing suggestions for adopting comprehensive technology and important references for the future development of the food traceability field. Qian, Jianping, and others reviewed the progress of traceability systems for processed foods and proposed various traceability methods including physical separation, batch definition, isotope analysis, DNA tracing, data statistical models, internal system development, artificial intelligence, and blockchain [14]. By comparing the advantages and disadvantages of various methods and applying them comprehensively in application scenarios, the traceability accuracy can be improved. Current research often lacks systematicity and integration when applying these technologies, so achieving full-process food information traceability is difficult. This article proposes an integrated food information traceability system by combining IoT and blockchain technology, aiming to enhance the real-time integration and transparency of supply chain information.

3. Design and Implementation of Supply Chain Food Information Traceability Model.

3.1. **Model Architecture.** The model architecture for information traceability mainly consists of four parts, namely, data collection, data transmission and storage, blockchain data management, and information display and query. Each component plays a crucial role in the research, ensuring data transparency, real-time performance, and security throughout the entire supply chain process. The architecture diagram of the overall model is shown in Figure 1.

Figure 1 shows the basic structure of the supply chain and information traceability model for food information. The functions of the entire model are mainly divided into data collection, transmission and storage, data management, and display queries. The data collection is the basic part of the entire model and the leading link in information tracing. Through IoT technologies such as radio frequency identification (RFID) tags, environmental sensors, and Global Positioning System (GPS) devices, real-time monitoring of food can be achieved at various stages of the supply chain, collecting relevant information about food in the supply chain. The supply chain includes the source of food, production and processing of food, information on the production of food products, ordering and delivery information, and consumer evaluation, all aim at achieving comprehensive food information. In the supply chain of the ordering platform, all process information of food—from production and processing to being sold to customers by merchants—can be recorded on the blockchain without omission. This provides extensive operational space for information traceability and ensures the accuracy and stability of

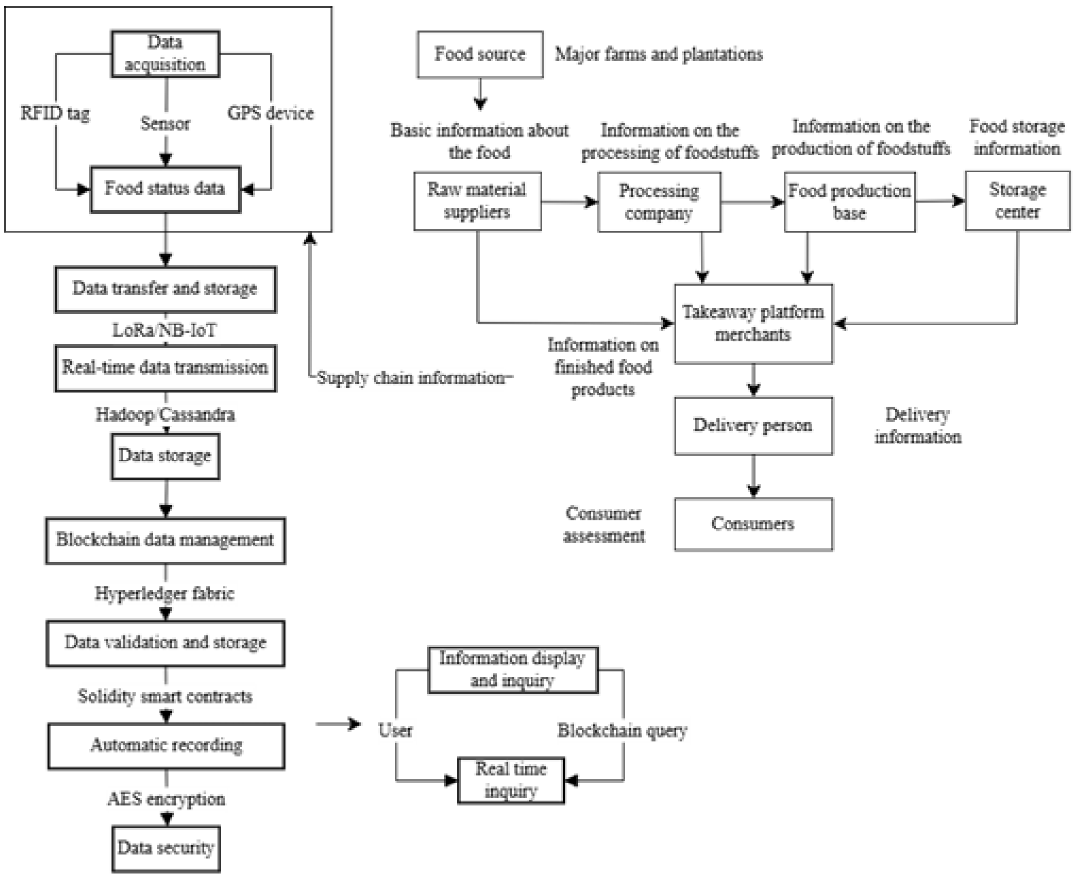

Figure 1. Architecture of Food Information Traceability Model

traceability. The data collection module is responsible for collecting data from all parts of the supply chain. The data storage module utilizes blockchain technology to ensure the data integrity and tamper-resistance. The smart contract module automatically enforces the terms of the contracts in the supply chain to ensure transparency and efficiency.

In addition to data collection, the transmission and storage of data, data management in blockchain, and the display and query of traceability information are critical links, jointly playing a role in improving information efficiency and ensuring data security [15, 16]. To ensure the operability and replicability of the system, this paper describes in detail the configuration and deployment steps of the blockchain platform. The data transmission and storage part adopts advanced wireless network technology and distributed storage system, enabling rapid data retrieval and real-time update to maintain data consistency and integrity. The blockchain data management part utilizes the Hyperledger Fabric blockchain platform, combined with Solidity smart contracts, to achieve automatic recording, verification, and storage of data. The information display and query part provides real-time query and display functions of food traceability information via a user interface.

Through the collaborative work of these functional modules, full-process management from data collection, transmission, and storage to display has been achieved, improving the real-time integration and transparency of supply chain information, thereby effectively ensuring food safety and quality.

3.2. **Data Collection.** Data collection is the fundamental link in implementing a food information traceability system for the supply chain of a food ordering platform based on BD and the IoT. This section mainly deploys relevant equipment to collect real-time status data of food in various links of the supply chain, ensuring that the status and position of each food unit in the entire supply chain can be accurately recorded and monitored. Table 1 shows some of the tools used and their purposes.

Table 1. Introduction of Tools

Serial Number	Tool/Environment	Description	Purpose
1	RFID Tags	Electronic tags utilizing radio waves for data transmission and storage	Automatic identification and tracking
2	Temperature Sensors	High-precision,low-power temperature sensors	Real-time monitoring of cold chain temperature
3	GPS Devices	High-precision positioning system	Real-time tracking of transportation routes and locations
4	Central Data Platform	Integrated data processing system	Data reception, cleaning, and storage

As shown in Table 1, the data collection process of the food traceability system involves multiple key tools and environments. RFID tags are used to automatically identify and track food throughout the entire supply chain. High precision, low-power temperature sensors monitor cold chain temperature are used to ensure food safety. GPS devices can track transportation routes and locations in real-time, ensuring transparency and traceability. All collected data can be processed and stored on a central data platform, which integrates data receiving, cleaning, and storage functions for comprehensive analysis and management.

RFID tags can be installed on food packaging and transportation containers to achieve automatic identification and tracking of food at various stages of the supply chain [17, 18]. This requires selecting RFID tags suitable for food packaging and transportation environments, ensuring that they can function properly under different temperatures, humidities, and physical pressures. UHF RFID tags can be used because of their long reading distance and strong anti-interference ability. RFID tags can be fixed in a prominent position on food packaging or transportation containers so that the RFID reader can scan the tag information smoothly. The installation position of the tag should avoid physical damage and interference from the external environment. RFID readers can be deployed at key nodes in the supply chain, such as production workshops, warehouse centers, distribution vehicles, and terminal stores. The scanning frequency and range of the readers can be configured for the real-time capture of tag information. The tag ID, reading time, location, and status information read from the tag can be uploaded in real-time to the central data platform through wireless networks (long-range radio or LoRa and narrow band IoT or NB-IoT) to complete automated food information collection.

To improve the comprehensiveness and flexibility of the system, this study introduces temperature sensors, humidity sensors, light sensors and GPS modules into the system. These sensors can collect key environmental parameters of food products in real time during production, transportation and storage and upload the data to the blockchain platform via network protocols such as LoRa and NB-IoT. The integration of multiple sensors improves the system's applicability and enables it to adapt to the traceability needs of different types of food.

Installing temperature sensors in the cold chain transportation and storage process can monitor the temperature of the food environment in real time, guaranteeing the reliability and food safety of the cold chain [19]. High precision and low-power temperature sensors can be selected to ensure stable operation in cold chain environments. Temperature sensors can be installed at key locations in cold chain transport carriages and storage equipment to accurately reflect ambient temperature. The position of the sensor should avoid heat sources and cold air blowing directly so that the measurement data has a certain representativeness. The temperature sensor data is uploaded in real time to the central data platform through wireless network, and the collection frequency of temperature data is set according to actual needs. By default, data are collected every 10 minutes. Temperature thresholds can be set on the central data platform. When the data collected by temperature sensors exceed the safe range, the system automatically triggers an alarm and notifies relevant management personnel to take measures to ensure food safety. In addition to factors such as temperature that considerably affect food transportation and storage, other factors should be considered based on actual food supply demand. Environmental conditions such as humidity and light can also affect certain foods.

GPS devices can be installed on transport vehicles to track food transportation routes and locations in real time, ensuring transparency and traceability during transportation [20]. GPS modules that support Global Navigation Satellite System (GLONASS) and Beidou dual-mode positioning can be selected to improve positioning accuracy and reliability. GPS devices can be installed in concealed locations on transport vehicles so that they are not easily damaged or interfered with by external factors. They are connected to the vehicle's power system to ensure continuous power supply during transportation. The location information collected by GPS devices can be uploaded in real time to the central data platform through wireless networks, and the frequency of location data collection should be set according to actual needs. Transportation routes can be set on the central data platform. When the location information collected by GPS devices deviates from the preset route, an alarm can be automatically triggered and relevant management personnel can be notified to take measures to guarantee the safety and controllability of the transportation process. Table 2 presents the collected relevant information about food in the ordering supply chain.

Table 2. Food Information in the Ordering Supply Chain

Serial Number	Food Name	Origin	Processing Information	Finished Product Information	Transportation Temperature	User Evaluation
1	Beef Steak	MN	Cut into pieces,frozen	Beef steak with sauce	-18°C	Fresh, tender meat
2	Organic Veggies	SD	Washed, graded, packaged	Vegetable salad	2–4°C	Good taste, well hydrated
3	Salmon	NO	Deboned, sliced, vacuum packed	Grilled salmon with herbs	-4°C	Fresh taste, few bones
4	Green Tea	ZJ	Picked, steamed, dried	Green tea drink	Room temperature	Strong aroma, sweet aftertaste
5	Eggs	HN	Washed, disinfected, packaged	Scrambled eggs	5 –10°C	Fresh, rich yolk

Table 2 presents information on various foods in the ordering supply chain, collected and displayed through a BD IoT-based ordering platform. For example, food item number 1 is a beef steak sourced from the MN region and processed through cutting and freezing. The finished product is a steak with sauce, requiring transportation at a low temperature of −18°C to maintain its freshness and safety. User feedback indicated that the meat was fresh and tender and had a smooth texture. This detailed information not only helps consumers understand the quality of the food but also provides transparency across all links in the supply chain, ensuring full traceability and safety from the source to the dining table.

The central data platform receives data from various devices and classifies and stores them. The Hadoop distributed file system (HDFS) and Cassandra database can be used for data storage, ensuring efficient storage and management of large-scale data. The raw data collected by the sensors are pre-processed, including denoising, formatting, and calibration, to maintain data consistency and reliability. The pre-processed data are transmitted to the edge computing nodes for initial analysis and filtering. Only key data are uploaded to the blockchain for storage, reducing unnecessary data transmission and improving the efficiency of the system. BD processing technology can be used to perform real-time analysis and processing of data, extracting valuable information. The processed data can be integrated into a blockchain data management system, which automatically records and verifies the data through smart contracts. Users can view real-time food traceability information through the information display and query system, ensuring transparency and traceability of the information.

3.3. **Data Transmission and Storage.** Data transmission and storage are important components of the food information traceability system. They ensure that data collected from various sensors can be transmitted and stored in real time and securely on the central data platform. Table 3 shows the transmission and storage methods used.

Table 3. Data Transmission and Storage Methods

Method/Tool	Description	Purpose	Problem Solved
LoRa	Low-power wide-area network	Long-distance data transmission	Reduces energy consumption
NB-IoT	Low power, narrow bandwidth wireless communication technology	High-density data transmission	Ensures stable data transmission
HDFS	Distributed file system	Large-scale data storage	Ensures data high availability
Cassandra Database	Distributed database	Real-time data query and high concurrency	Provides efficient storage and management
Secure Sockets Layer/ Transport Layer Security Protocol	Security protocols	Data encryption during transmission	Prevents data interception and tampering

LoRa technology is suitable for long-distance, low data rate application environments and is ideal for data transmission at various nodes in the supply chain. NB-IoT is a cellular-based narrowband IoT technology with the advantages of wide coverage, low power consumption, and stable connection. It is suitable for high-density data transmission in urban environments. Through these technologies, data collected by other devices (RFID tags, temperature sensors, and GPS devices) are transmitted in real time to a central data platform. The sensors pack and send the data to the nearest LoRa gateway or NB-IoT base station through the built-in communication module. After receiving the sensor data, these gateways and base stations transmit the data to the central data platform through the Internet or a dedicated data channel.

To ensure the integrity and real-time performance of data transmission, the system optimizes the transmission protocol and packet format. Custom data compression algorithms can be used to reduce packet size and improve transmission efficiency. The system can use checksum technology to ensure the integrity of data during transmission. It can set a retransmission mechanism, and when the transmission fails, the system can automatically resend the data to ensure that the data is not lost.

HDFS has the characteristics of high reliability and scalability and can process and store a large amount of data from different sensors [21, 22]. HDFS stores data in chunks on multiple nodes and generates multiple replicas for each data chunk to ensure high availability and fault tolerance of the data. The Cassandra database is used to meet the needs of real-time data queries and high concurrency access [23]. Cassandra is a highly available, single point of failure free distributed database suitable for handling large-scale structured and unstructured data. Cassandra achieves efficient storage and management of data through data sharding and replication strategies. Each data fragment is distributed across different nodes, and each fragment has multiple replicas to ensure high availability and consistency of the data. To optimize the data storage structure, this system adopts a blockchain storage scheme based on hash index. This scheme considerably improves the efficiency and accuracy of data query by generating a unique hash index for each record. In addition, the system introduces a hierarchical storage architecture. It stores historical data in the cold storage node and keeps real-time data in the hot storage node to accelerate the access speed of frequently used data and further improve the query efficiency.

After the data are uploaded to the central data platform, they should be cleaned and processed. Extract, Transform, Load tools facilitate the extraction, transformation, and loading of the received data, removing duplicate and abnormal data and ensuring the accuracy and completeness of the data [24, 25]. The cleaned data are loaded into HDFS and Cassandra databases for storage and management. Through BD processing technology, the system conducts real-time analysis and processing of data, extracts valuable information, and integrates it into the blockchain data management system. The data are automatically recorded and verified through smart contracts.

Multi-level data encryption and access control strategies are used during data transmission and storage. To prevent data from being tampered with or leaked during transmission, the system introduces a multi-layer encryption and authentication mechanism during data transmission. It encrypts the data through the SSL/TLS protocol and verifies each piece of data with digital signature technology to prevent them from being stolen or tampered with during transmission. During the storage process, AES encryption algorithm is used to encrypt sensitive data to guarantee the security of data in the storage process. In addition, access to the data is restricted through role authority control so that only authorized users can access and operate the data. Distributed storage technology is used to decentralize the storage of sensitive user information in multiple nodes, and the data in each node are encrypted independently, further enhancing the protection of user privacy.

3.4. **Blockchain Data Management.** This article adopts the Hyperledger Fabric blockchain platform, combined with Solidity smart contracts and AES encryption algorithm, to achieve automatic recording, verification, and secure storage of data, thereby ensuring the authenticity, transparency, and immutability of data [26, 27]. Figure 2 shows the blockchain structure used in this article.

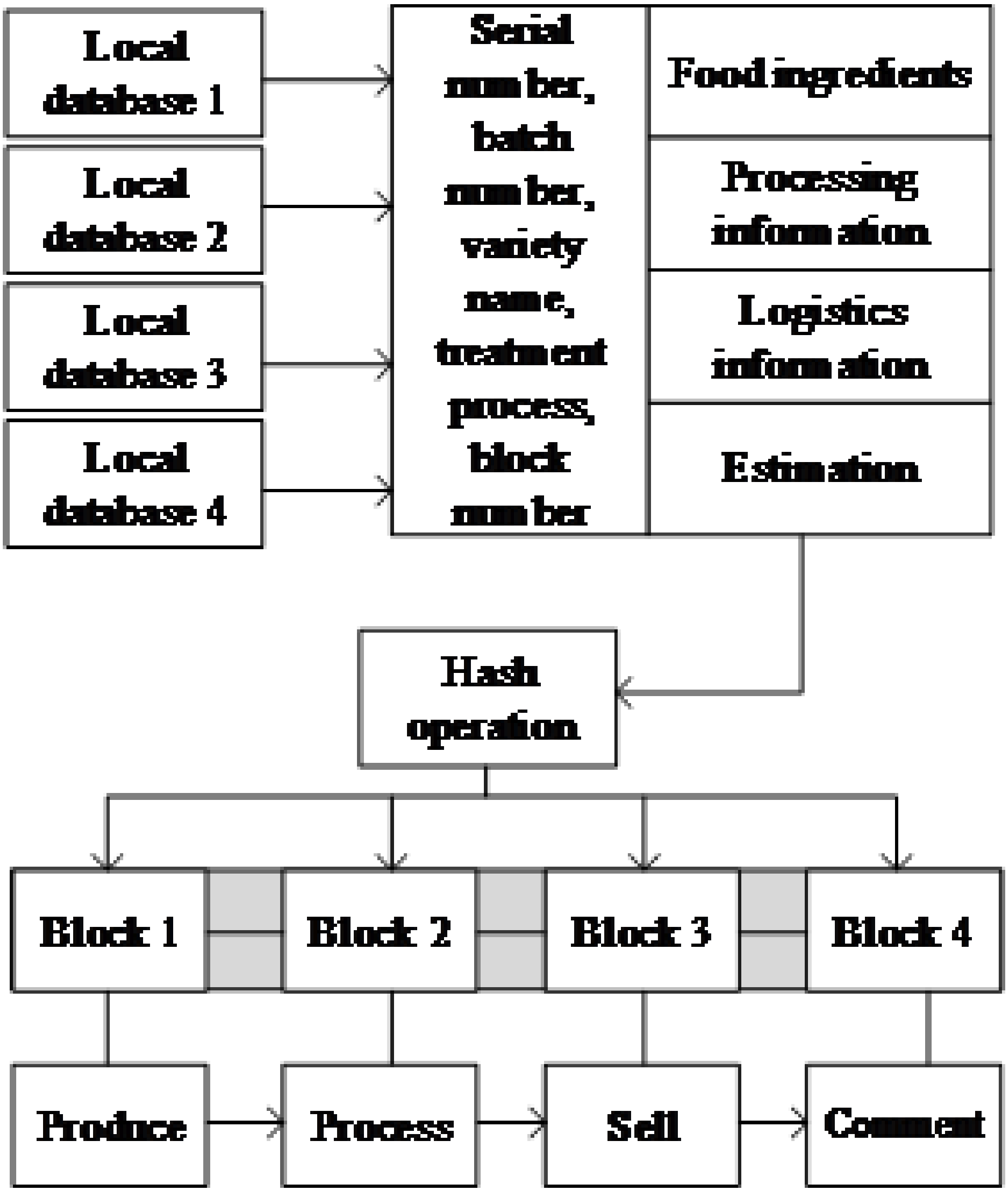

Figure 2. Blockchain Design Structure

The general structure of blockchain is presented in the form of a flowchart. Local databases 1 to 4 store key information such as food serial numbers, batch numbers, variety names, processing techniques, logistics information, and evaluations. These pieces of information are integrated through hash operations to form blocks, each containing relevant information for the four stages of production, processing, sales, and review. This design enables complete and accurate recording of food information and has a high degree of transparency and immutability.

Hyperledger Fabric is suitable for complex SCM owing to its modularity and high scalability. During the configuration process, multiple nodes are deployed, including sorting nodes and peer nodes. Sorting nodes are responsible for sorting transactions and packaging them into blocks, and peer nodes are responsible for maintaining ledger data and executing smart contracts. By creating channels to isolate and protect transaction data, different parties interact with one another through their respective channels to maintain data privacy and security.

To ensure the identity authentication of participating nodes and the security of data transmission, the system sets up a certificate authority to generate and manage digital certificates. Each transaction is signed by the parties involved using a digital certificate to ensure the non-repudiation and integrity of the transaction.

Smart contracts are automated programs on the blockchain that can automatically execute transactions and record data based on preset conditions. Solidity can be used to write smart contracts that automatically record and verify data at various stages of the supply chain. Data structures related to food traceability can be defined in smart contracts, including production information, processing information, transportation information, and sales information. Smart contract logic is written to ensure that relevant data is automatically recorded on the blockchain when food passes through various nodes in the supply chain. Each data record includes a timestamp, participant ID, and transaction details to ensure data integrity and traceability.

To ensure data security, the system uses AES encryption algorithm to encrypt sensitive data [28]. Before uploading data to the blockchain, AES algorithm can be used to encrypt the data. The encryption key is managed by the system, and only authorized users can decrypt and view the data. Encryption keys can be managed through Hyperledger Fabric's certificate authority to ensure their security and validity. Authorized users can obtain encrypted data through the system interface and decrypt it using the corresponding decryption key when querying data, guaranteeing the confidentiality and integrity of the data during transmission and storage.

3.5. **Information Display and Query.** In the food information traceability system, information display and query are key links to maintain data transparency and user trust. To this end, modern web development technology and application programming interface (API) integration are adopted, and a user-friendly interface and efficient data query mechanism are designed to enable consumers and regulators to conveniently access the full lifecycle information of food.

React and Vue front-end frameworks are used to develop the user interface [29]. To improve the user experience, this study adopts a user-friendly interface layout and operation flow in the system design. The interface design focuses on intuitiveness and friendliness and adopts responsive design to ensure compatibility across different devices. Components such as search bar, data display form, timeline, and charts are developed and tested independently in a modular manner to ensure functional modularity and code reusability. The backend is developed using Node or Django, providing RESTful API interfaces to integrate with the Hyperledger Fabric blockchain platform. Data queries can be performed through API interfaces, covering functions such as food information queries and data filtering. To improve query efficiency, indexes can be created for commonly used queries in the database, and caching technologies such as Redis can be used to accelerate query response time. Data visualization libraries such as D3 and Chart can be used to display the production, processing, transportation, and sales information of food in the form of charts, enhancing the readability and understanding of the data [30]. The timeline component can display the full lifecycle information of food, clearly presenting the entire process from production to sales.

To realize information sharing and system interoperability, this study explores the compatibility of this system with other food traceability systems. The system exchanges data with other systems through a standardized data interface and supports the parsing and conversion of multiple data formats, ensuring smooth communication. In addition, this study analyzes the compatibility challenges in cross-platform applications and proposes a solution based on blockchain cross-chain technology to achieve broad food traceability information sharing [31, 32, 33].

3.6. **Food Safety Emergency Response.** In this paper, an emergency response mechanism is designed to deal with emergencies such as food recall. The system can automatically trigger an early warning and initiate a recall procedure when an abnormality is detected through real-time monitoring of key parameters in the food distribution process. The system simultaneously records the operation logs of each link through the blockchain to ensure that the source of the problem can be traced back quickly after the incident occurs and that corresponding measures can be taken timely.

4. **Evaluation of the Effectiveness of Supply Chain Information Traceability.**

4.1. **Data Integrity and Accuracy.** Simulation experiments were conducted to evaluate the data integrity and accuracy of supply chain information traceability. Experiments started by recording data from the source of food and comparing blockchain records with actual data. Several food samples were used in the experiment, and data were collected in real time through RFID tags, temperature sensors, and GPS devices at various stages of production, processing, transportation, and sales. These data were uploaded to the central data platform and recorded on the blockchain to generate tamper-proof records. The raw material information in the records was read and compared with the sample data to obtain the evaluation indicator data.

In data integrity verification, the data integrity of the system was evaluated by counting the missing data in different stages. The missing data rate is defined as the ratio of missing data to total recorded data, and the specific experimental data are shown in Figure 3.

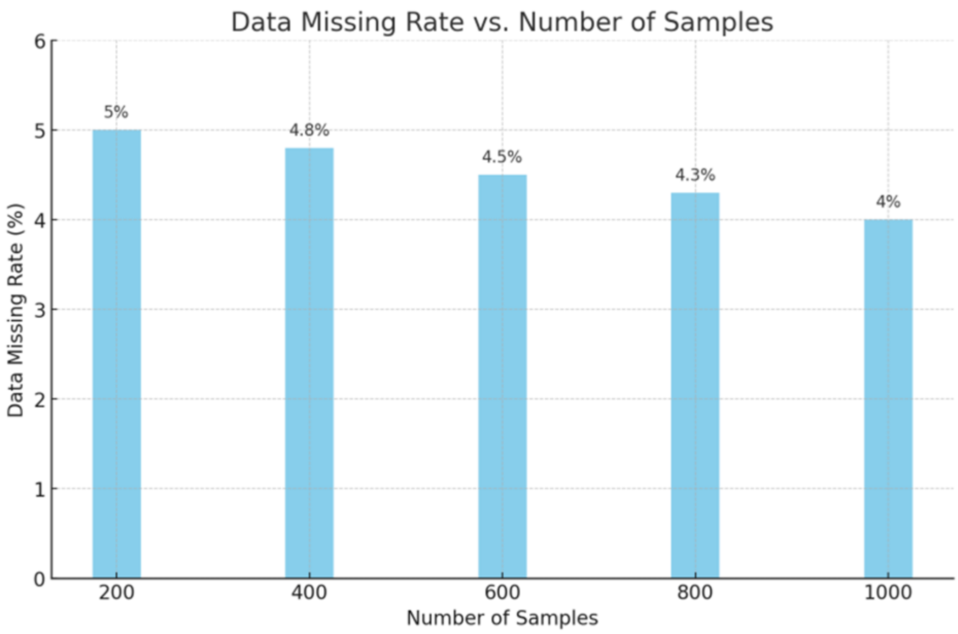

Figure 3. Data Loss Situation under Different Sample Sizes

In Figure 3, the missing data rate is shown at different sample sizes. With the increase of sample size, the missing data rate gradually decreases. The missing rate decreases from 5% for 200 samples to 4% for 1000 samples, indicating that as the sample size increases, the integrity of data collection improves. These results validate the data integrity performance of supply chain information traceability under different sample sizes, providing a basis for subsequent analysis and improvement.

In data accuracy verification, data bias was quantified, and data accuracy was evaluated by calculating the mean square error (MSE). The formula for MSE is

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(D_{s,i} - D_{b,i})^2 \tag{1}$$

where n is the number of data records, and $D_{s,i}$ and $D_{b,i}$ are the ith records of actual data and blockchain data, respectively. This study imported data from 200 food samples; compared the timestamp, location, and status information of the records; calculated the differences between each record; and finally calculated the MSE. The specific data changes of MSE for the two types of food are shown in Figure 4 to observe the differences in recording effects of different types of food intuitively.

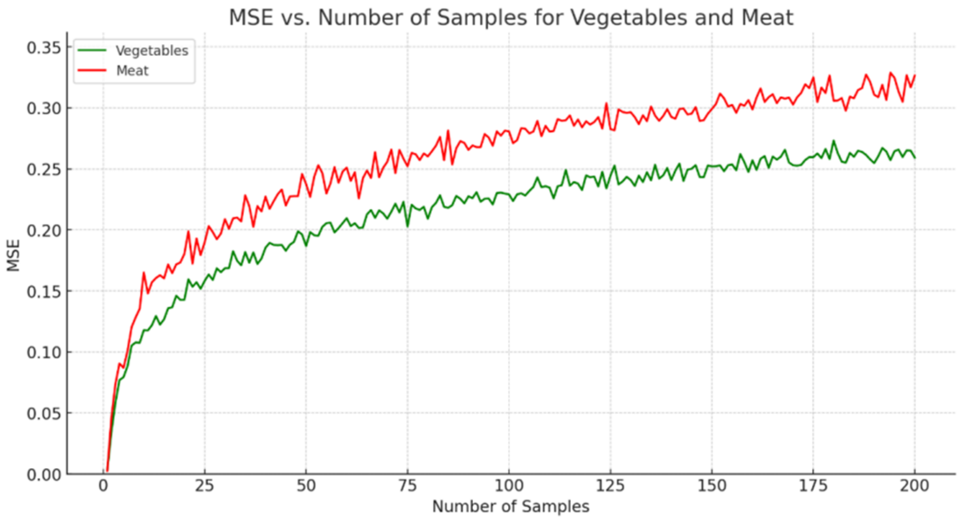

Figure 4. MSE Changes of Vegetables and Meat Foods

Figure 4 shows the changes in the MSE of vegetables and meat products from 1 to 200 samples. MSE is an indicator that measures the difference between predicted and true values, with lower values indicating higher prediction accuracy. Figure 4 reveals that the MSE of both foods fluctuates to an extent, but the overall trend gradually stabilizes with the increase of sample size. The MSE of vegetables is stable at around 0.25, and that of meat is stable at around 0.30. The MSE fluctuation of vegetables is smaller than that of meat products. This result indicates that the characteristics of meat products are more complex and diverse, leading to higher difficulty in prediction. This fluctuating and stabilizing trend reflects the actual situation in the data collection and recording process, which helps understand the accuracy performance of different types of food in the supply chain traceability system.

The experimental results show that the missing data rate and MSE of each link are low, indicating that the system performs well in terms of data integrity and accuracy. Through these methods, this study systematically evaluates the data integrity and accuracy of the supply chain information traceability system, providing a solid foundation for subsequent traceability and analysis.

4.2. **Real-time Performance.** Real-time performance plays an important role in supply chain information tracing because it directly affects the effectiveness of data and the timeliness of decision making. Ensuring real-time transmission and processing of data at all stages can not only improve the transparency of the supply chain but also enhance the efficiency of food safety supervision. Therefore, this study designed and implemented a series of experiments to evaluate the real-time performance of the system at different stages.

The timestamp T_s of sensor data generation and the timestamp T_r of data arrival at the platform were recorded at each stage (production, processing, transportation, sales), and the transmission delay ΔT for each data was calculated as follows:

$$\Delta T = T_r - T_s \tag{2}$$

Statistical analysis was performed on the transmission delay data of each link, and the average delay $\overline{\Delta T}$ and standard deviation $\sigma_{\Delta T}$ were calculated. The formulas are as follows:

$$\overline{\Delta T} = \frac{1}{n}\sum_{i=1}^{n} \Delta T_i \tag{3}$$

$$\sigma_{\Delta T} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\Delta T_i - \overline{\Delta T})^2} \tag{4}$$

Where n is the number of data samples, and ΔT_i is the transmission delay of the ith data. Figure 5 shows the delay distribution diagram for verifying real-time performance.

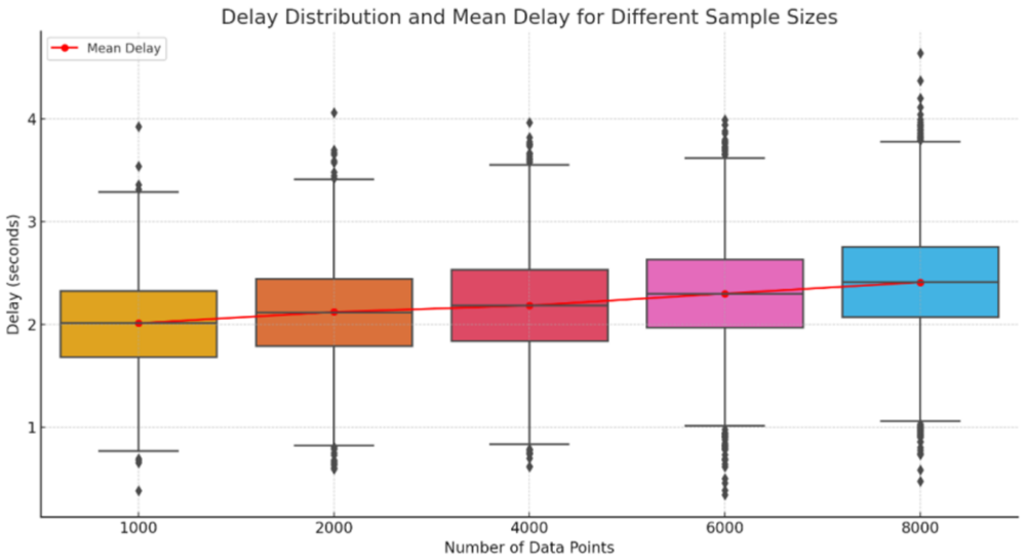

Figure 5. Transmission Delay under Different Data Volumes

Figure 5 shows the delay distribution under different data volumes. The box plot in the figure shows the distribution of delays for various data sizes, including median, upper and lower quartiles, and outliers. The red line chart represents the average delay for each data volume. As the amount of data increases, the distribution of latency gradually stabilizes, and the average latency slightly increases. This indicates that the real-time performance of the system remains at a good level in the case of large amounts of data. However, as the amount of data increases, the response time of the system may be extended. Figure 5 provides data support for optimizing the supply chain information traceability system.

To verify the performance of the system in different network environments, this study tested the response time and data transmission speed of the system in three network environments, namely, Wi-Fi, 4G LTE and NB-IoT. The results show that in the Wi-Fi environment, the system has the shortest response time and the highest data transmission speed. Although the data transmission speed is relatively slow in the NB-IoT environment, the system performs stably and is suitable for low-power and long-distance application scenarios.

The experimental results show that the average transmission delay of each link is within an acceptable range, and the proportion of data that meets real-time standards is relatively high. If the transmission delay of certain links is substantial, the data transmission network and device configuration must be optimized. Through these experiments and analyses, the real-time performance of the supply chain information traceability system was verified, providing a basis for system optimization.

4.3. **User Satisfaction.** User satisfaction is an important indicator for measuring the effectiveness of a system, optimizing food regulation by understanding feedback from consumers and regulatory agencies. To evaluate user satisfaction, this study designed and implemented a series of questionnaire surveys to collect feedback from consumers and regulatory agencies. The questionnaire uses the Likert Scale, with a rating range of 1 to 5, where 1 represents very dissatisfied and 5 represents very satisfied. Table 4 shows users' evaluation of the ordered food.

Table 4. Consumer Evaluation Form

User ID	Food Quality	Food Freshness	Food Taste	Packaging Quality	Delivery Time	Overall Satisfaction
1	4	4	4	4	3	4
2	5	4	4	5	4	5
3	3	3	4	4	3	3
4	4	4	3	3	4	4
5	4	5	4	4	5	4
6	5	4	5	5	4	5
7	3	3	3	3	3	3
8	4	5	4	4	5	4
9	5	4	5	5	4	5
10	4	4	5	4	3	4

Table 4 shows that users 1 to 10 provided comprehensive evaluations on food quality, freshness, taste, packaging quality, and delivery time. User 1 gave a score of 4 for food quality, freshness, taste, and packaging quality, reflecting good satisfaction. However, they only gave a score of 3 for delivery time, indicating that the delivery time was slightly longer or did not meet expectations. The overall satisfaction score is 4, implying that users are satisfied with the service as a whole. The analysis of these users' evaluations reveals that the majority of them gave high ratings for food quality, freshness, and taste. However, some users raised higher expectations for delivery time. The feedback help the ordering platform continuously improve service quality and enhance overall user satisfaction.

To comprehensively assess the food quality, this study introduces multi-dimensional user evaluation information into the system. In addition to traditional ratings and comments, the system captures user-specific feedback on food safety, taste, packaging, and other aspects. These data can be analyzed to provide targeted improvement suggestions for all parties in the supply chain, which can help improve the overall food quality.

4.4. **Food Safety.** Food safety is a key objective of SCM, and the implementation of information traceability aims to reduce the occurrence of food safety incidents and improve the overall level of food safety. This study designed and implemented a series of experiments to collect data on food safety incidents, including food contamination, spoilage, and expiration, within six months before and after implementation. The number and severity of events were recorded and classified into three categories: mild, moderate, and severe. Food safety incidents before and after the experiment for six months were classified and counted, and the number of each type of incident was recorded. The experimental results are shown in Figure 6.

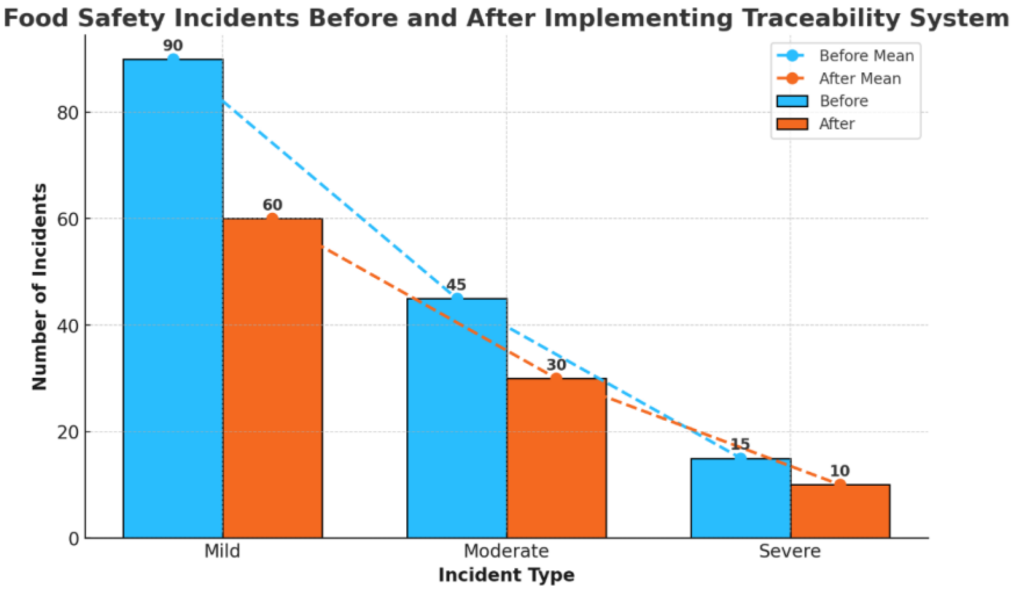

Figure 6. Comparison Before and After Food Safety Experiment

After implementing the traceability system, the number of various food safety incidents considerably decreased. Taking minor incidents as an example, the average number of incidents before implementation was 90, which decreased to 60 after implementation. Moderate incidents decreased from 45 to 30, and the number of severe incidents decreased from 15 to 10. This outcome indicates that optimizing the traceability of food information can effectively reduce the probability of food safety issues, especially for minor and moderate problems. By combining sensors and blockchain technology, the real-time integration and transparency of supply chain information can be improved, thereby effectively ensuring food safety and quality.

4.5. **Application Cases.** The application effect of the system was verified through two actual cases: dairy products supply chain and seafood products cold chain logistics. In the dairy supply chain, the system utilizes blockchain technology to track the whole process from raw material procurement to finished product sales. Consumers can scan the QR code on the products to obtain detailed production and transportation records, which greatly improves the transparency of supply chain information and food safety. In the case of cold chain logistics of seafood products, the system records the temperature and humidity of each link in the transportation process through sensors and uploads the data to the blockchain platform in real time. The full monitoring and information transparency of cold chain logistics is realized, ensuring the quality and safety of seafood products.

5. **Conclusions.** This article focuses on food information traceability in the supply chain of a BD IoT ordering platform. By using sensors and blockchain technology, the real-time

integration and transparency of supply chain information are improved, thereby ensuring food safety and quality. The specific methods include using RFID tags, temperature sensors, and GPS devices for data collection, utilizing wireless network technologies such as LoRa and NB-IoT for data transmission, and automatically recording and verifying data through the Hyperledger Fabric blockchain platform combined with smart contracts. The experimental results show that the system performs well in terms of data integrity, accuracy, real-time performance, and user satisfaction. The number of food safety incidents has substantially decreased, verifying the effectiveness of the system. Regarding application prospects, it can enhance the transparency of food safety regulation, improve the efficiency of supply chain management, and enhance consumer trust in the production process.

However, this study also has certain shortcomings. The performance and scalability in large-scale applications still need further optimization, and the high cost of data collection equipment may affect its widespread promotion. Future research can focus on optimizing system performance, reducing equipment costs, and combining artificial intelligence technology to further enhance SCM efficiency and food safety assurance capabilities. A more efficient and secure food SCM system can be achieved through these improvements.

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REFERENCES

[1] Ehuwa, Olugbenga, Amit K. Jaiswal, and Swarna Jaiswal. "Salmonella, food safety and food handling practices." Foods 10.5 (2021): 907-907.

[2] Li, Shubo, Tian, Yufeng Jiang, Pingyingzi Lin, Ying Liu, Xiaoling Yang, Hongshun, et al. "Recent advances in the application of metabolomics for food safety control and food quality analyses." Critical reviews in food science and nutrition 61.9 (2021): 1448-1469.

[3] Koch, Julia, Britta Frommeyer, and Gerhard Schewe. "Online shopping motives during the COVID-19 pandemic—lessons from the crisis." Sustainability 12.24 (2020): 10247-10247.

[4] Aryani, Dwi Nita, Nair, Rajesh Kumar Hoo, Dana Xing Yue Hung, Daisy Kee Mui Lim, Deborah Hong Ru Chew, Wei Ping, et al. "A study on consumer behaviour: Transition from traditional shopping to online shopping during the Covid-19 pandemic." International Journal of Applied Business and International Management (IJABIM) 6.2 (2021): 81-95.

[5] Qian, C., Murphy, SI Orsi, RH Wiedmann, M. "How can AI help improve food safety?." Annual Review of Food Science and Technology 14.1 (2023): 517-538.

[6] Rana, Roberto Leonardo, Caterina Tricase, and Luigi De Cesare. "Blockchain technology for a sustainable agri-food supply chain." British Food Journal 123.11 (2021): 3471-3485.

[7] Yu, Zhilong, Jung, Dongyun Park, Soyoun Hu, Yaxi Huang, Kang Rasco, Barbara A, et al. "Smart traceability for food safety." Critical Reviews in Food Science and Nutrition 62.4 (2022): 905-916.

[8] Yuan, Chunlin, Shuman Wang, and Xiaolei Yu. "The impact of food traceability system on consumer perceived value and purchase intention in China." Industrial Management & Data Systems 120.4 (2020): 810-824.

[9] Balamurugan, S., A. Ayyasamy, and K. Suresh Joseph. "IoT-Blockchain driven traceability techniques for improved safety measures in food supply chain." International Journal of Information Technology 14.2 (2022): 1087-1098.

[10] Mondal, Saikat, Wijewardena, Kanishka P, Karuppuswami, Saranraj, Kriti, Nitya, Kumar, Deepak, Chahal, Premjeet, et al. "Blockchain inspired RFID-based information architecture for food supply chain." IEEE Internet of Things Journal 6.3 (2019): 5803-5813.

[11] Bhat, Showkat Ahmad, Huang, Nen-Fu, Sofi, Ishfaq Bashir, Sultan, Muhammad. "Agriculture-food supply chain management based on blockchain and IoT: a narrative on enterprise blockchain interoperability." Agriculture 12.1 (2021): 40-40.

[12] Casino, Fran, Venetis Kanakaris, Thomas K. Dasaklis, Socrates Moschuris, Spiros Stachtiaris, Maria Pagoni, et al. "Blockchain-based food supply chain traceability: a case study in the dairy sector." International journal of production research 59.19 (2021): 5758-5770.

[13] Lei, Moyixi, Xu, Longqin Liu, Tonglai Liu, Shuangyin Sun, Chuanheng. "Integration of privacy protection and blockchain-based food safety traceability: Potential and challenges." Foods 11.15 (2022): 2262-2262.
[14] Qian, Jianping, Dai, Bingye Wang, Baogang Zha, Yan Song, Qian. "Traceability in food processing: Problems, methods, and performance evaluations—A review." Critical Reviews in Food Science and Nutrition 62.3 (2022): 679-692.
[15] Xu, Min, Xingtong Chen, and Gang Kou. "A systematic review of blockchain." Financial innovation 5.1 (2019): 1-14.
[16] Gorkhali, Anjee, Ling Li, and Asim Shrestha. "Blockchain: A literature review." Journal of Management Analytics 7.3 (2020): 321-343.
[17] Kantareddy, Sai Nithin R., Mathews, Ian Bhattacharyya, Rahul Peters, Ian Marius Buonassisi, Tonio Sarma, Sanjay E, et al. "Long range battery-less PV-powered RFID tag sensors." IEEE Internet of Things Journal 6.4 (2019): 6989-6996.
[18] Herrojo, Cristian, Moras, Miquel Paredes, Ferran Nunez, Alba Mata-Contreras, Javier Ramon, Eloi, et al. "Time-domain-signature chipless RFID tags: Near-field chipless-RFID systems with high data capacity." IEEE Microwave Magazine 20.12 (2019): 87-101.
[19] Shin, Jaeho, Jeong, Buseong Kim, Jinmo Nam, Vu Binh Yoon, Yeosang Jung, Jinwook, et al. "Sensitive wearable temperature sensor with seamless monolithic integration." Advanced Materials 32.2 (2020): 1905527.
[20] Thoelert, Steffen, Steigenberger, Peter Montenbruck, Oliver Meurer, Michael. "Signal analysis of the first GPS III satellite." GPS Solutions 23.4 (2019): 92-92.
[21] Merceedi, Karwan Jameel, and Nareen Abdulla Sabry. "A comprehensive survey for hadoop distributed file system." Asian Journal of Research in Computer Science 11.2 (2021): 46-57.
[22] Elkawkagy, Mohamed, and Heba Elbeh. "High performance hadoop distributed file system." International Journal of Networked and Distributed Computing 8.3 (2020): 119-123.
[23] Jakkula, Prashanth. "HBase or Cassandra? A comparative study of nosql database performance." International Journal of Scientific and Research Publications 10.3 (2020): 808-820.
[24] Yulianto, Ardhian Agung. "Extract transform load (ETL) process in distributed database academic data warehouse." APTIKOM Journal on Computer Science and Information Technologies 4.2 (2019): 61-68.
[25] Mallek, Hana, Faiza Ghozzi, and Faiez Gargouri. "Towards extract-transform-load operations in a big data context." International Journal of Sociotechnology and Knowledge Development (IJSKD) 12.2 (2020): 77-95.
[26] Melo, Carlos, Oliveira, Felipe Dantas, Jamilson Araujo, Jean Pereira, Paulo Maciel, Ronierison, et al. "Performance and availability evaluation of the blockchain platform hyperledger fabric." The Journal of Supercomputing 78.10 (2022): 12505-12527.
[27] Komleva, Nataliia, and Oleksandr Tereshchenko. "Requirements for the development of smart contracts and an overview of smart contract vulnerabilities at the Solidity code level on the Ethereum platform." Herald of Advanced Information Technology 1.6 (2023): 54-68.
[28] Lu, Zhimao, and Houmed Mohamed. "A complex encryption system design implemented by AES." Journal of Information Security 12.2 (2021): 177-187.
[29] Vyas, Rishi. "Comparative analysis on front-end frameworks for web applications." International Journal for Research in Applied Science and Engineering Technology 10.7 (2022): 298-307.
[30] Mei, Honghui, Guan, Huihua Xin, Chengye Wen, Xiao Chen, Wei. "Datav: Data visualization on large high-resolution displays." Visual Informatics 4.3 (2020): 12-23.
[31] Zhang, X., He, X., Du, X., Zhang, A., & Dong, Y. (2023). Supply Chain Practices, Dynamic Capabilities, and Performance: The Moderating Role of Big Data Analytics. Journal of Organizational and End User Computing, 35(3), 1-26.
[32] Gao, Y., Wang, J., Li, Z., & Peng, Z. (2023). The Social Media Big Data Analysis for Demand Forecasting in the Context of Globalization: Development and Case Implementation of Innovative Frameworks. Journal of Organizational and End User Computing, 35(3), 1-15.
[33] Wang, Q., Zong, B., Lin, Y., Li, Z., & Luo, X. (2023). The Application of Big Data and Artificial Intelligence Technology in Enterprise Information Security Management and Risk Assessment. Journal of Organizational and End User Computing, 35(1), 1-15.