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Research on Risk Management in Milk Supply Chain Based on Blockchain Technology

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Abstract: *With the increasing concern of consumers about food quality and safety, the transparency and traceability of agricultural food supply chains have become crucial. This study focuses on the milk supply chain and explores how blockchain technology can be utilized to improve risk management. Leveraging the characteristics of distributed ledger, smart contracts, and immutability offered by blockchain, the transparency of the milk supply chain can be enhanced, reducing information asymmetry and effectively lowering potential quality and safety risks. The research will emphasize the application of blockchain in various stages of milk production, transportation, storage, and sales, as well as its role in traceability, verification, and trace-back. Through in-depth analysis, this study aims to provide a more secure, efficient, and reliable solution for milk supply chain management, contributing new ideas and methods for the sustainable development of the food industry.*

Keywords: *blockchain, milk, traceability system*

1. Introduction

With the increasing concern in society about food quality and safety, the challenges in managing the agricultural food supply chain have become more significant. In this context, milk, as an indispensable component of people's daily diet, requires transparency and traceability in its supply chain to ensure consumer rights and uphold food safety. However, traditional supply chain management systems often face issues such as information asymmetry, data tampering, and difficulties in traceability, posing threats to the sustainable development of the food industry.

Blockchain technology, as a decentralized, distributed ledger system, offers new possibilities to improve food supply chain management. This research aims to explore, using the example of the milk supply chain, how blockchain technology can enhance risk management capabilities.

Firstly, the distributed ledger characteristics of blockchain technology are expected to eliminate information asymmetry in traditional supply chains, enabling real-time sharing and updating of data records. Secondly, the use of smart contracts can automate compliance checks and relevant business rules, enhancing the operational efficiency of the supply chain. Most importantly, through the application of blockchain technology, we can establish a traceable system to swiftly and accurately trace the origin of products, strengthening quality control and risk prevention.

2. What is Blockchain

Blockchain is a revolutionary technology with its core concept centered around building a decentralized, distributed ledger system. This system consists of individual blocks, each containing a certain amount of transaction information and cryptographic details related to the previous block, such as a hash value. These blocks are interconnected in a chain, forming a continuously growing data chain.

Decentralization is one of the primary characteristics of blockchain. Unlike traditional central authorities or servers, blockchain does not rely on a single management entity; instead, it distributes data across multiple nodes in the network. Each node maintains a copy of the entire chain, enhancing the system's robustness and resistance to attacks.

The distributed ledger of blockchain ensures that all participants can view the same data, thereby increasing the system's transparency. This also helps prevent data tampering, as any modifications to a previous block are immediately detected once data is written to the blockchain, ensuring the immutability of the data through the use of encryption techniques and hash functions.

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The transparency of blockchain makes data visible to all participants, establishing a foundation of trust. This is crucial for preventing fraud and building reliable business relationships. Refer to Figure 1 for the structure of the blockchain.

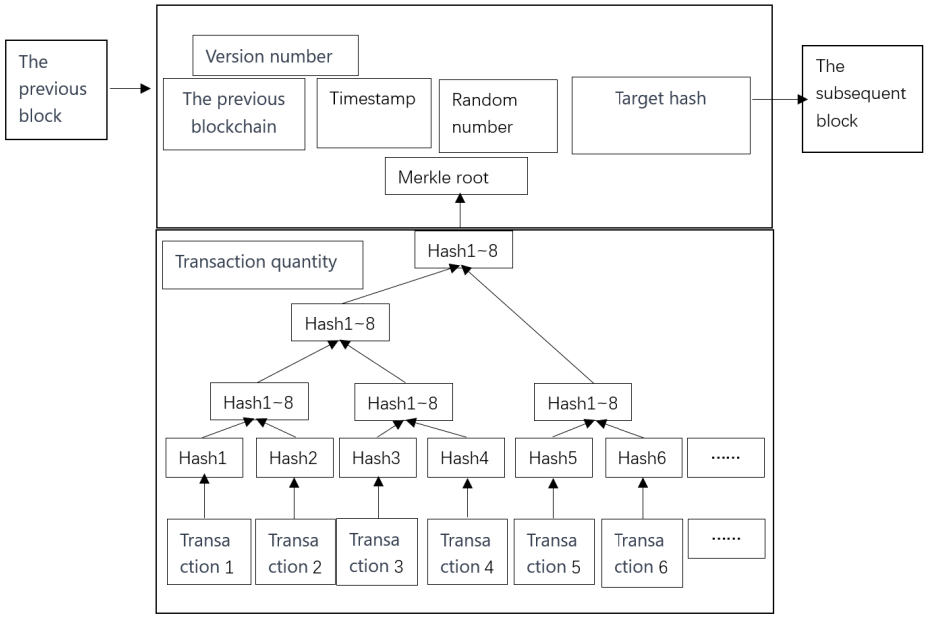

Figure 1: Blockchain Structure Diagram.

The primary application of blockchain technology is to protect data. Regardless of the node it is on, once data tampering occurs, it will be detected in the next link, leading to a thorough investigation to identify the point of tampering. Therefore, the use of blockchain technology significantly enhances the security and reliability of data circulation, making information more transparent throughout the process. [1]

3. The problems faced by the milk product supply chain

In the milk product supply chain, ensuring that products meet specific quality standards is crucial, including aspects such as freshness and hygiene. Any quality issues that arise during production, processing, or transportation may lead to product damage or recalls, resulting in adverse effects on the entire supply chain. Therefore, establishing a comprehensive traceability system is essential for maintaining quality control in milk products.

To ensure the quality and safety of milk products, the foundation lies in establishing a robust traceability system. Adopting advanced technologies such as blockchain and RFID enables end-to-end traceability, covering the entire process from production sources to the hands of consumers. This approach ensures the authenticity and reliability of information. Detailed records in the milk production process, including aspects like pasture management, feed sources, and dairy cow health, are particularly critical. These pieces of information not only contribute to improving product quality but also assist in identifying the origin of quality issues when they arise, enabling more precise problem resolution and improvement.

A consortium blockchain, applied within alliance organizations, consists of chains formed by groups or partial organizational entities. Members in the alliance collectively undertake accounting responsibilities, and each organization member can serve as an accounting node.[2] Smart contracts are deployed within the alliance after consensus negotiation. This approach enhances the security and reliability of information sharing, fostering trust and improving the efficiency of the traceability system. Through consortium blockchain technology, the milk supply chain can better safeguard product quality and safety, ensuring that consumers can confidently purchase high-quality milk products.

In the processing and manufacturing stages of milk, recording and tracing each step are crucial to ensuring product quality. Emphasis is placed on identifying potential sources of contamination introduced during the processing process and using a traceability system to recognize and eliminate these issues, thereby ensuring product safety and hygiene standards. The analysis covers how to track products

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during milk transportation and distribution, addressing issues such as temperature fluctuations and cross-contamination. Emphasis is placed on the importance of recording and monitoring data during transportation to enhance the quality preservation of products and reduce the risks that may lead to quality problems.

The discussion explores the role of traceability systems in product recalls, including how to quickly determine affected batches and scope. The critical role of traceability systems in rapid response, issue resolution, and harm mitigation is emphasized, ensuring quick and effective action in case of problems. The discussion also delves into how traceability information can be shared with consumers to enhance product transparency and trust. Emphasis is placed on providing consumers with easily understandable information, enabling them to understand the product's origin, production process, and quality standards, thereby boosting their confidence in the product.

Analyzing regulations and standards for food traceability in various regions is crucial to ensure manufacturers fulfill their compliance responsibilities. Establishing a traceability system is highlighted as a key means to meet regulatory requirements, contributing to sustained compliance for businesses in the global market.

Challenges encountered in establishing and maintaining traceability systems are discussed, along with potential technological innovations to address these challenges. The continuous development of technology is emphasized for improving the efficiency and feasibility of traceability systems, making them more adaptable to the evolving production environment.

By addressing traceability issues, milk producers can establish a more reliable, transparent, and efficient supply chain system, thereby enhancing product quality, ensuring food safety, and ultimately strengthening brand reputation and consumer trust.

During the transportation of milk, the cold chain system may face malfunctions, leading to insufficient temperature control. This issue can trigger a series of far-reaching impacts, primarily involving the quality, safety, and commercial aspects of milk products.

In terms of quality, milk, being a perishable food item, is susceptible to accelerated bacterial growth and spoilage if the temperature is not controlled. Inadequate temperature can also cause the precipitation of fat and proteins in milk, affecting its texture and taste. Concerning safety, improper temperature may lead to bacterial growth, including pathogens, increasing the risk of bacteria and microorganisms in milk. Under high-temperature conditions, bacteria may also produce toxins, further raising the risk of consumers contracting food poisoning.

In the realm of commercial impact, the discovery of milk quality issues may necessitate product recalls, incurring significant costs, including transportation, processing, and damage to market reputation. Decreased product quality may also result in customer dissatisfaction, harming brand reputation and affecting long-term customer loyalty.

In terms of regulatory compliance, insufficient temperature control may violate food safety regulations, leading to legal responsibilities and fines. Regarding traceability, the lack of a traceability system may hinder the rapid determination of the source of problems when temperature control issues lead to a decline in milk quality, delaying the resolution of issues.

4. Information Traceability System for Milk Products

The blockchain-based traceability and authentication system for the milk product supply chain have incomparable advantages compared to traditional models.[3] The Information Traceability System for all milk products is a system that utilizes technological means to track, record, and showcase the entire process of milk production. Such a system helps ensure the quality, safety, and traceability of milk products.

Here are potential elements that may be included in an information traceability system:

4.1 Production Stage Information

4.1.1 Pasture Information

In the information traceability system for milk products, pasture information is a crucial component designed to trace the origin of milk production. Each batch of milk produced should be accurately

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recorded with its source pasture. This involves detailed pasture information such as geographical location, farming environment, and climatic conditions. By documenting this data, the system ensures the tracking of the living conditions of the cattle, including the cleanliness of the barns, water sources, and temperature, providing a robust foundation for milk production. The system should also track and record the health status of the cattle, which may include regular veterinary checks, vaccination records, and the treatment history of diseased cows. Such information ensures the good health of the cattle during the production stage, thereby influencing the quality and safety of the final milk product.

4.1.2 Feed Information

Feed, as the primary nutritional source for dairy cows, directly influences the quality of milk based on its types, sources, and quality. Therefore, in the information traceability system for milk products, tracking feed information becomes particularly important. The system should meticulously record the types of feed used for feeding dairy cows, including grass, feed grains, and other additives. The source of the feed should also be documented to ensure the safety and compliance of the feed. For instance, if a batch of feed originates from a specific farm, the system should be able to trace back to the production standards and inspection results of that farm. Recording quality information for the feed is also essential, including nutritional components and the use of preservatives. Through comprehensive tracking of feed information, it ensures that dairy cows receive sufficient and balanced nutrition, thereby producing high-quality milk products.

4.2 Production Process Information

During the production process, each batch of milk should be clearly defined, labeled, and recorded. This includes assigning unique identifiers such as production date and batch number to each batch for traceability throughout the entire production process. By meticulously recording the production process for each batch, the system enables end-to-end traceability, allowing quick identification of specific batches when issues arise, facilitating effective problem resolution and recalls.

The hygiene and safety of production equipment are crucial factors in ensuring milk quality. Therefore, the information traceability system should record relevant information about the equipment and machinery used in milk production, including equipment model, production date, and maintenance records. Additionally, monitoring and recording the operational status of equipment ensure hygiene and safety during the production process. Comprehensive records of regular maintenance and inspections are also essential to ensure that the equipment remains in efficient operation.

4.3 Quality Control Information

Comprehensive quality testing for all milk is crucial. The system should record the assay results for each batch of milk, including but not limited to fat content, protein content, bacterial levels, etc. These data not only help ensure that the milk meets standards but also provide robust support for quality control throughout the production process. Temperature control is essential for the freshness and safety of milk during production, storage, and transportation. The information traceability system should monitor and record temperature changes in milk at different stages to ensure suitable temperatures are maintained throughout the entire supply chain. This helps prevent premature spoilage of milk or quality issues due to temperature fluctuations.

4.4 Packaging and Shipping Information

Packaging is a crucial step in preventing milk from contamination. The information tracing system should record the packaging materials used and relevant details of the packaging process. This includes the packaging date, packaging process, and materials used. By tracking packaging information, it can ensure that milk maintains good hygiene during the packaging process. Recording the entire distribution chain from the production site to the hands of consumers is part of ensuring product freshness and safety. The information tracing system should track key information during the distribution process, including transportation means, transportation temperature, and delivery time. This helps promptly identify and address potential issues that may affect product quality, such as temperature fluctuations or cross-contamination.

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4.5 Electronic traceability identification

To ensure that each product batch can be uniquely identified and traced, the system can use RFID technology or barcodes. By using RFID tags or barcodes, each product batch can be assigned a unique identity. This identification method makes tracking and retrieving product information throughout the supply chain more efficient and accurate. Whether it is batch management during the production process or consumer queries, these electronic identifiers play a crucial role.

4.6 Information disclosure and inquiry

To enhance product transparency, the system should provide a consumer inquiry platform. This platform allows consumers to scan the product's barcode or enter the batch number to retrieve relevant product information. Through this method, consumers can learn about the product's production origin, quality information, and other related data, thereby increasing trust in the product. To further improve transparency, some information can be publicly displayed within the system. This may include the product's place of production, production date, quality inspection results, and more. A transparent public display system helps consumers gain a more comprehensive understanding of the product's production process and quality standards, allowing them to confidently choose and purchase the product.

4.7 Security and Privacy Protection

The system needs to adopt a series of security measures to ensure the confidentiality of information. This includes technical measures such as encrypted communication, access control, authentication, etc., to prevent unauthorized access and data leaks. Especially for information involving personal privacy and business secrets, it is necessary to establish robust security measures. To ensure that the system complies with relevant regulations and standards, particularly those related to personal privacy and data protection, a sound compliance assurance system needs to be established. This may include regular compliance reviews, compliance testing, to ensure that the system design and operation comply with legal requirements and protect the rights of consumers and producers.

Implementing such a traceability system can help improve the quality of dairy products, reduce food safety risks, and enhance consumer trust in the products. The system structure is depicted in (Figure 2).

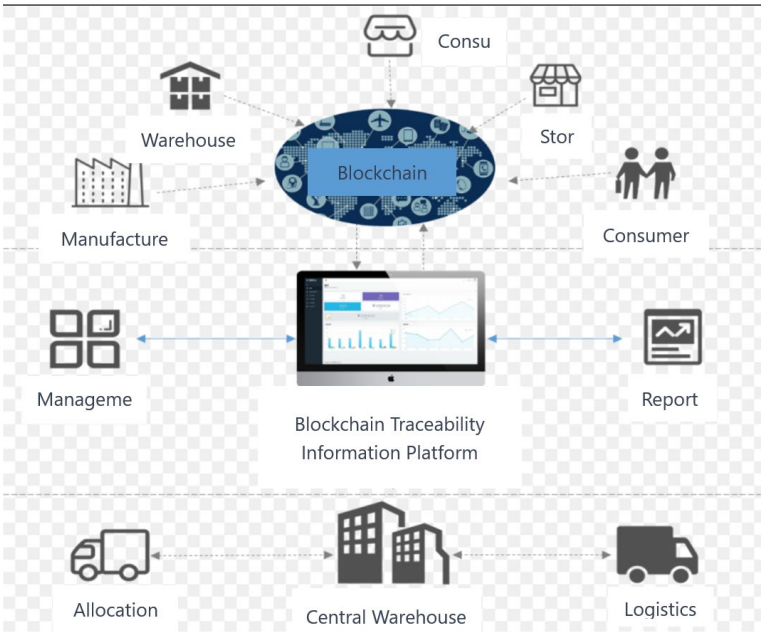

Figure 2: Traceability System Information Structure Diagram.

5. Conclusions

The research on a blockchain-based milk supply chain traceability system provides an innovative solution for modern agriculture and food safety. By integrating the immutability, transparency, and

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distributed ledger features of blockchain, the system can effectively trace the production, processing, transportation, and sale of milk, enhancing transparency and traceability throughout the entire supply chain. In the study, we delve into the application of blockchain technology in the milk supply chain and design a comprehensive traceability system. The system covers key steps such as data recording in the production process, monitoring of processing, real-time tracking of transportation, and validation in the sales process. Through the use of smart contracts, the system can automatically perform compliance checks, ensuring that each step complies with relevant standards and regulations.

During the implementation of the system, privacy and data security issues of all stakeholders are considered. By employing blockchain encryption technology and permission control mechanisms, information visibility is restricted to authorized personnel, protecting user privacy and business confidentiality. The research results indicate that the blockchain-based milk supply chain traceability system has achieved significant effects in improving food safety, reducing information asymmetry, lowering risks, and enhancing consumer trust. However, the implementation of the system still faces challenges, including the standardization of technical standards, collaborative efforts among stakeholders, and cost control.

Overall, the blockchain-based milk supply chain traceability system offers an innovative solution for the food industry, laying the foundation for a more reliable, transparent, and secure supply chain. Future research and practice should continue to focus on continuous optimization of technology, further improvement of standards, and collaborative efforts from various sectors to drive greater success in practical applications.

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