Blockchain-Based Risk Tracing of Animal-Derived Food Supply Chain

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Abstract

The animal-derived food supply chain is lengthy and complex, and each link has certain risk factors. This paper analyzed the potential risks in the supply chain in order to ensure the safety of animal-derived food and the traceability of supply chain risks. Combining blockchain with the traditional animal-derived food supply chain, we proposed a risk-tracing model. Finally, we constructed a risk-tracing system based on Hyperledger Fabric. The results show that the system realizes the whole-process supervision of animal-derived food safety to ensure data transparency and traceability in the entire supply chain, so as to ensure the food safety of animal-derived food.

Keywords

blockchain; animal-derived food; supply chain; risk-tracing

1. Introduction

Food safety has become a major concern for society in recent years. The food supply chain is complex, with information asymmetry in each link, low information transparency, and difficulties with quality and safety traceability [1]. Traditional supply chain systems rely on centralized data storage, which makes it difficult to recover when the central data is lost. Using blockchain technology to achieve information security, traceability, and transparency in the food supply chain has become a research hotspot. Blockchain technology can ensure that all data is not tampered with, and information can be traced [2]. But, there is relatively little research on risk analysis in each link of the food supply chain, especially for the specific scenarios of animal-derived food supply chain risk tracing. Compared with other food supply chains, the structure and links of the animal-derived food supply chain are more complex. Problems in any link will cause safety problems, and the traceability of risks in its supply chain is particularly important.

This paper first introduced the concept of blockchain technology, and then analyzed the risks in all links of the animal-derived food supply chain. Aiming at the problems existing in the traditional animal-derived food supply chain, this paper constructed a safety risk-tracing model with blockchain technology and realized the risk-tracing system based on the Hyperledger Fabric technology architecture.

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2. Introduction of bockchain concept and risk analysis of animal-derived food supply chain

2.1. Concept of blockchain technology

Blockchain is a decentralized distributed database ledger [3], which is a data structure containing blocks of transaction information linked by time sequence [4]. It adopts a peer-to-peer network structure. Transactions can occur directly between nodes without third-party auditing [5]. Blockchain data is maintained by all nodes, which greatly enhances the authenticity of recorded data. The blockchain uses timestamp technology to link the information on the chain in chronological order, recording the complete history of blockchain transactions and enabling traceability of any one transaction [6]. Once the data is written into the blockchain, it will be stamped with a timestamp. As a proof of the existence of the block data, no one can easily tamper with the transaction information, which has high security. In addition to the encrypted private information of the transaction parties, anyone can query the blockchain data and develop related applications through the open interface, so the information of the whole system is highly transparent. The asymmetric encryption mechanism of blockchain can generate keys for each transaction in the food supply chain, enabling data encryption, digital signatures, and login authentication. The data upload operation of each link in the supply chain will be attached with a digital signature to ensure that the data of each link cannot be forged.

2.2. Risk analysis of animal-derived food supply chain

There are certain risk factors in each link of the animal-derived food supply chain, from animal breeding, slaughtering, production and processing, storage and transportation, catering production, to wholesale and retail sales [7]. This section analyzed the risks in each link of the animal-derived foods supply chain to lay the foundation for the risk tracing of the entire supply chain.

(1)Raw and auxiliary material risks. The main ingredients and accessorial ingredients of food generally have the risks of food-borne stimulants, allergens, genetically modified organisms, and unidentified irradiation treatments. For sports events, it is very important to strictly control the supply chain of animal-derived food and effectively reduce the risk of food-borne stimulants [8].

(2)Risks in livestock breeding and slaughtering. In livestock breeding and slaughtering, there are mainly risks of chemical inputs, pollution, and illegal drug addition. Pollution risks include environmental pollution, feed pollution, veterinary drug pollution, disease livestock and poultry pollution, and pathogenic bacteria pollution. The risks of illegal addition include the illegal addition of veterinary drugs, the illegal addition of food additives, etc.

(3) Food production and processing risks. The main sources of food safety risks in the entire supply chain are risks in food production and processing [9]. Food production and processing links have certain risk factors, such as food additives beyond the scope and limit of use, thermal processing temperature and time is not insufficient to lead to excessive microorganisms, packaging is not disinfected or damaged, resulting in biological and chemical pollution.

(4) Food circulation risks. When the circulation conditions change, there are certain food safety risks [10], such as excessive total bacterial count due to improper storage conditions.

(5) Catering production risks. With reference to the announcement of the State Administration for Market Regulation on the issuance of food safety operating specifications for catering services [11], there are three main risks in the catering production link: raw material input; pollution in the process of production; and pollution in the state of ready-to-eat.

The above is the risk analysis of the animal-derived food supply chain in each link. The focus of food safety risk control is to record the risks in each link in detail so that information supervision and traceability of the whole supply chain may be facilitated.

3. Model construction and system design

Based on the above risk analysis of the animal-derived food supply chain, we simulated the business scenario of safety risk traceability in the supply chain and constructed and designed the system model combined with blockchain technology. We realized the risk traceability of the supply chain through the query and call of intelligent contracts.

3.1. Blockchain architecture of animal-derived food supply chain

In the blockchain-based food supply chain traceability system, each node is independent of each other, and the storage consistency is maintained and guaranteed through the consensus mechanism. At the same time, the independence of each node prevents the loss of information in any link of the supply chain and affects the overall operation of the system, ensuring the security of the system. The blockchain architecture of the animal-derived food supply chain includes the application layer, control layer, consensus layer, network layer, and data layer.

The application layer encapsulates the application scenarios of the animal-derived food supply chain. Through the application layer, the risks involved in each link of the supply chain can be integrated, and the whole process can be traced.

The control layer consists of process models, smart contracts, and various script codes. Smart contracts can realize standardized supply chain information entry through automatic execution, solving the problem of low efficiency in manual processing of events. The contract is programmable, enabling the flexible expansion of business logic.

The consensus layer encapsulates various consensus algorithms. The blockchain relies on a consensus mechanism to ensure the unification of the entire network of data stored and maintained by each node. Early blockchains adopted a PoW (Proof of Work) mechanism that relies on computing power to ensure accounting consistency [5]. With the continuous development of blockchain technology, researchers have proposed mechanisms such as PoS (Proof of Stake), DPoS (Delegated Proof of Stake) [12], and PBFT (Practical Byzantine Fault Tolerance) [13].

The network layer encapsulates the network structure and communication mechanisms of the blockchain system. Each node on the blockchain communicates through the peer-to-peer mechanism to jointly maintain the consistency of the blockchain ledger. The data layer includes transaction data blocks, timestamps, public keys, private keys, encryption mechanisms, etc. It is the lowest data structure of the entire blockchain system. It adopts hash algorithms, asymmetric encryption, and other technologies to realize the reliability and security of transactions. This study adopted an on-chain and off-chain dual-chain data storage mode combined with an offline database. Blockchain storage was interconnected with relational database storage.

3.2. Design of supply chain risk-tracing model

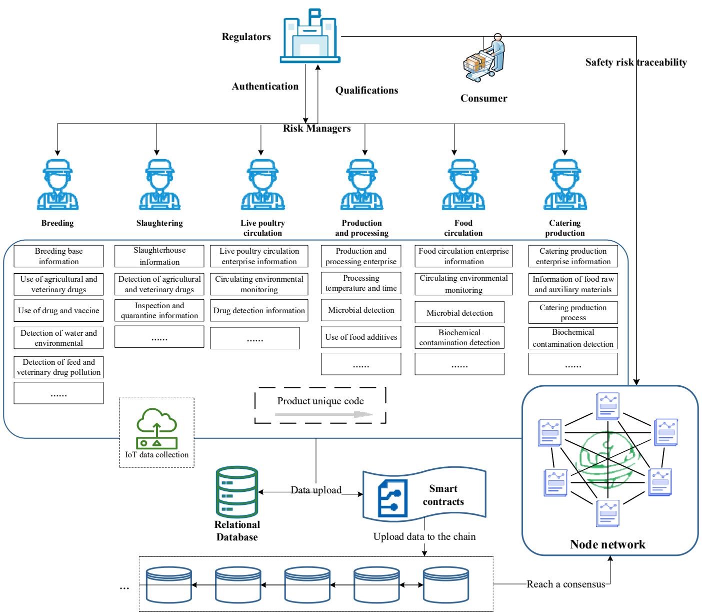

Fig.1 Risk tracing model of animal-derived food supply chain

This study, combined with the research on blockchain technology and the corresponding blockchain network nodes of enterprises in other food-related fields, designed the nodes and risk-tracing process corresponding to the supply chain links and established a risk-tracing model covering all links of the supply chain.

As shown in Figure 1, risk managers in each link upload and maintain data to ensure the reliability of data sources. Each livestock and poultry will be bound with a unique code before slaughter. All the recorded information is called to the smart contract to be uploaded to the chain. After each node receives the information, it is verified by the consensus algorithm to reach a storage agreement. A digital signature will be attached after the information from each link is successfully uploaded to the chain. Each link corresponds to multiple nodes. Each node contains all the contents of the blockchain and jointly uploads and maintains the data. After the nodes reach a consensus, the whole life cycle of the product identified by the code will be completely recorded on the blockchain. Consumers and regulators can quickly trace any link in the supply chain through this system to effectively ensure the quality and safety of food.

3.3. Smart contract design of animal-derived food supply chain

Based on the business scenario of risk tracing in the animal-derived food supply chain, this research designed smart contracts to realize data uploading and realize the traceability function through query and call. Smart contracts define the access mode to the ledger. The ledger can be queried or updated through the functions in the smart contract. After the smart contract is installed and instantiated on the node, the client application can interact with the blockchain ledger through the smart contract.

4. Experiment and result analysis

4.1. Experimental environment

Hyperledger Fabric needs to run in a Linux environment. The system run on the Ubuntu Linux v16.04 operating system under a VMware virtual machine. The front-end was built based on the RuoYi-Vue framework, using Node.js as the middleware to connect the front-end and the blockchain server, and storing data in the blockchain by calling smart contracts. At the same time, the hash value of the data will generate blocks through consensus, and the blocks will be stored in the blockchain ledger and transmitted to the front-end blockchain browser. The relational database used MySQL to record key information at each link of the animal-derived food supply chain. Picture files such as livestock and poultry growth status and quarantine certificates were stored in the FastDFS distributed file system. The blockchain network used a single-machine multi-node deployment method, with five organizations in the consortium chain, including one order node and five peer nodes, to realize data upload and maintenance in each link.

4.2. Experimental results

Through the analysis of each link of the animal-derived food supply chain, combined with the application scenarios of the blockchain, this research designed a blockchain-based animal-derived food supply chain risk-tracing system. Through this system, the operation of each link in the supply chain was simulated and uploaded to the chain. Finally, the tracing source code generated in the catering production and sales process was used to trace the risk of the whole process of food. Figure 2 shows the blockchain browser. You can see the current block information and node information. Figure 3 shows the details of the whole process of breeding livestock and poultry. The breeding base files the livestock and poultry breeding and records and uploads the data of additives and drug use involved in the livestock and poultry breeding process. Figure 4 is the food tracing page based on the food tracing source code, showing the risk characteristic information of animal-derived food from livestock and poultry breeding to final catering and retail. Consumers and regulators can quickly query the information contained in each link of the supply chain. This page also shows the blocks generated by each link. You can view the details of this block, including pre-hash, current block data hash, transaction ID, timestamp, and other information.

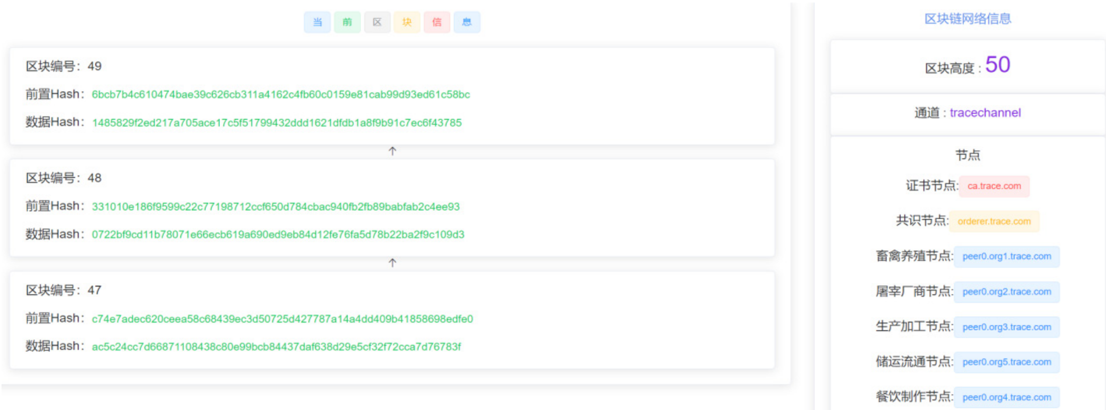

Fig.2 Blockchain browser interface

畜禽链上养殖过程详情

养殖过程ID	畜禽ID	药物使用	记录时间	投入品投放	环境监测	饮用水检测	备注	图片
6935612074361884672	6935608599997583360	驱虫药：伊维菌素	2022-05-26 23:26:15	非蛋白氮添加剂、胃酸缓冲剂	氨气20mg/m³，二氧化碳1300mg/m³，温度15℃，湿度80%	Fi=0.75，水质良好	黄曲霉素含量30μg/kg	
6935786802531799040	6935608599997583360	痢菌净拌料0.005%,泰妙灵(tiamulin) 饮水0.0125%	2022-05-27 11:00:34	营养素30g，尿素100g，瘤胃素0.2g	温度20℃，相对湿度75%	Fi=4.25，水质较好	饲料无污染，菌落数正常，黄曲霉素含量处于安全值范围	
6935809554110222336	6935608599997583360	中草药添加精饲料1.5%	2022-05-27 12:30:58	益生菌添加60g	CO2浓度25%，NH3浓度18%	Fi=5.10，水质良好	青饲料黄曲霉毒素检出率35%	
6935887130841321472	6935608599997583360	甲硝唑饮水0.02%～0.05%,拌料：0.05%	2022-05-27 17:39:14	维生素A、维生素D和维生素E	H2S：15mg/m³，CO2：800mg/m³，NH3：6mg/m³	Fi=0.85，水质优良	饲料监测无污染	

Fig.3 Example of livestock and poultry breeding process details on blockchain

Fig.4 Animal derived food supply chain risk-tracing interface

5. Conclusion

The blockchain has significant advantages, which make it have a wide range of application scenarios in the field of supply chains. This paper proposed a safety risk-tracing model of the animal-derived food supply chain based on blockchain technology and realized the safety risk-tracing system through experimental verification, which can provide a solution to the problems of information asymmetry and risk tracing in the animal-derived food supply chain. However, there are still some deficiencies in this study. For example, during data recording, even if the digital signature of blockchain technology can ensure a certain degree of data credibility, there is still the problem of insufficient reliability of data sources. It is necessary to further combine the Internet of Things technology to realize the automatic detection and transmission of data to ensure the credibility of data sources.

6. Acknowledgments

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7. References

[1] He, J. (2016) Food supply chain management. China Light Industry Press. Beijing.
[2] Ding, J.C., Wu, Q.L. (2021) Research review and develop prospects of food supply chain traceability system based on blockchain. J. Food & Machinery., 37(02): 72-77.
[3] Pearson, S., May, D., Leontidis, G., et al. (2019) Are Distributed Ledger Technologies the panacea for food traceability?. J. Global Food Security., 20: 145-149.
[4] Yang, H.Q., Sun, L., Zhao, X.C. (2018) Build mutual trust supply chain information system based on blockchain. J. Science & Technology Progress and Policy., 35(05): 21-31.
[5] Yuan, Y., Wang, F.Y. (2016) Blockchain：the state of the art and future trends. J. Acta Automatica Sinica., 42(4): 481-494.
[6] Liu, A.D., Du, X.H., Wang, N., et al. (2018) Research progress of blockchain technology and its application in information security. J. Journal of Software., 29(07): 2092-2115.
[7] Jin, H.S., Liu, Y.S. (2015) Risk identification and safety supervision and management of agricultural product supply chains.J. Food Science., 36(13): 265-271.
[8] Shi, L., Tan, B. (2022) Research status of stimulant pollution in food. J. Journal of Food Safety & Quality., 13(07): 2217-2222.
[9] Wang, J.N., Wang, Q., Chen, T.Q. (2019) Research on food safety risk management from the perspective of supply chain network. J. China Condiment., 44(12): 167-171.
[10] Sheng, J.P., Su, W.F., Luo, Y.B. (2020) Risk analysis and control in the field of food circulation. J. Science and Technology of Food Industry., 41(19): 240-243.
[11] State Administration for Market Regulation. (2019) Announcement of the State Administration of Market Regulation on the issuance of food safety operation specifications for catering services. https://www.samr.gov.cn/spjys/tzgg/201902/t20190226_291361.html.
[12] Yuan, Y., Ni, X.C., Zeng, S., et al. (2018) Blockchain consensus algorithms：the state of the art and future trends. J. Acta Automatica Sinica., 44(11): 2011-2022.
[13] Castro, M., Liskov, B. (2002) Practical byzantine fault tolerance and proactive recovery. J. ACM Transactions on Computer Systems., 20(4): 398-461.