A Discretization Traceability System for Food Risk Based on Blockchain and Health Code

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Abstract. In view of the opacity of the food supply chain and potential food safety issues, many companies and scientists suggest building traceability system (TS) to monitor food safety. However, the most of TSs are not very active caused by the low participation of enterprises and consumers. This paper proposes a collaborative food health traceability model to share the risk information of traceability products, improve the degree of freedom of related traceability through decentralized supply chain processes, and introduce the health code mechanism to set up a risk inspection rule. The results show that the traceability platform can increase the flexibility of companies to participate in traceability and the strength of data protection, and can improve the level of risk detection for consumers. In particular, the platform can alleviate the pressure of scarce regulatory resources. And in the case of problematic products, it can prevent secondary damage caused by related products in time, thereby improving user experience and platform activity.

Keywords: Food safety · traceability · blockchain · health code · collaborative supervision

1 Introduction

With the expansion of food production and consumption in China, the rapid development of the food industry can effectively alleviate the problem of food shortages in the domestic market [19] However, food safety incidents in recent years have exposed the deep-seated shortcomings of the food safety supervision mechanism, and food safety has attracted attention from all walks of life [15]. In the field of food safety, researchers and companies from all walks of life have proposed to establish food traceability platforms for monitoring [6].

With the development of the Internet of Things (IOT) and blockchain technology, many scientists have combined new technologies such as RFID, NFC, cloud computing and big data to develop a variety of blockchain traceability systems [1]. For example, Tian, F. [13] used HACCP (Hazard Analysis and Critical Control Points), blockchain

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and the Internet of Things to reduce the risk of centralized IT systems, and provide supply chain members with an open, transparent, and neutral information platform. Wang, J. et al. [14] proposed association rule mining technology and the Internet of Things to monitor and alert data. Hao, Z. et al. [8] combined blockchain technology and visualization technology to build a food accident risk analysis platform.

After more than ten years of development, food traceability technology has achieved certain success and implementation experience, and the food traceability model has gradually been recognized and accepted. Although there are many platforms, the current traceability platforms generally perform poorly, with low business participation and low frequency of consumer use. This is because consumers can only easily understand the source and cannot directly grasp the food safety risk, so there is no risk communication with relatives. In addition, full transparency results in manufacturers and distributors disclosing commercial dissemination data, which increases the risks of their commercial trades [4].

For the above reasons, we decided to focus on optimizing the architecture of the traceability system to ensure food traceability and risk communication during the traceability process, and to reduce the risk of exposure to circulating commercial data of the participating companies. In this research, we propose a collaborative food health traceability model to establish the core food traceability module, and used IOT and blockchain to set up a virtual traceability base station to reduce the cost of traceability, and linked different roles in the Food supply chain through smart contracts. Under the coordination of all parties, the platform maintains the health status of food traceability, realizes coordinated monitoring of food traceability by multiple parties, increases the credibility of food traceability and builds a trustworthy community. Aiming at different audiences, we adopt individualized access methods internally to promote the close integration of the actual retrospective application of multiple parties with the original business operations. At the same time, it can connect with the upstream and downstream of the supply chain to achieve full traceability, thereby enhancing the user experience.

2 Materials and Methods

2.1 A Collaborative Food Health Traceability Model Based on Blockchain

Open and mutually beneficial information exchange is essential for risk communication in traceability systems [7]. Based on the blockchain, we provide a universal food health monitoring model to share risk information of monitored products, and use the traceability and non-negotiation of the blockchain to ensure an effective monitoring system and safe risk communication.

The collaborative food health traceability model mainly consists of supply measurement, surveillance measurement, data-side measurement and data analysis measurement connected by the data analysis center. Supply measurement collects and transmits information about the movement of food through the supply chain [11]. The supervision of the side is mainly composed of supervision departments and testing institutions, aiming to input authoritative food supervision information in the process of traceability; The data side is composed of access blockchain service clusters, which store traceability and risk information persistently to ensure data security.

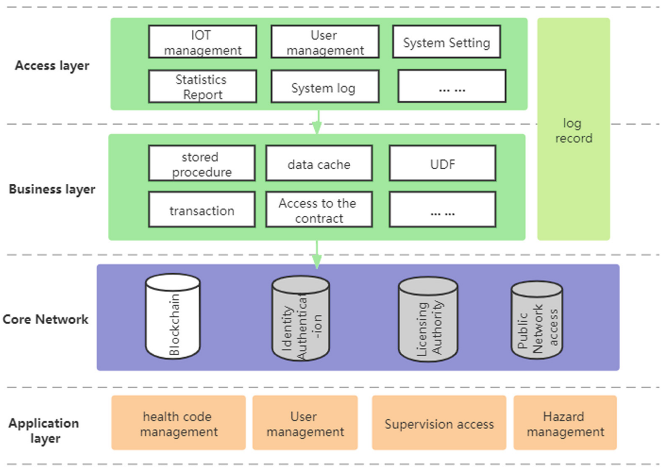

Fig. 1. The architecture of the system

2.2 System Architecture for Collaborative Traceability of Food Health

In order to implement the above model, reduce monitoring costs, and improve system performance and availability, we propose a system architecture with tracking system characteristics based on blockchain and the Internet of Things – Food Health Code traceability system (FHCTS). The basic architecture of the system comprises the access layer, business layer, core network and application layer. Figure 1 shows the architecture of the system.

2.2.1 Access Layer

The basic element of traceability is the traceability unit [5] and the responsibility of the FHCTS access layer is to establish the link between the traceability unit of the physical world and the traceability platform. Our manufacturing process mainly includes food labeling traceability, identification and external collection of critical information. On the one hand, most of the foods in circulation have outer packaging; On the other hand, barcodes and quick response (QR) codes are cheap and easy to use. Therefore, barcodes and QR codes are mainly used to track the identity of food. Identifying and externally collecting critical information from growers, producers and traders in the food supply chain using the Internet of Things to collect and transmit data, assets, logistics and transactional information. These devices communicate with the business layer.

2.2.2 Business Layer

The business layer comprises various business activities from agriculture to retail in the food supply chain (excluding consumption, see Sect. 4 Application layer). The main goal of the business layer is to split up the business and put in place a mechanism for data cache. We divide the food supply chain into agricultural producers, producers, distributors and retailers. The establishment of the business layer can be adapted to the internal mechanism of the company [3]. Using tea traceability as an example, tea farmers can adjust their settings to suit internal planting conditions, including soil, temperature and humidity, detecting heavy metals in the land and recording planting conditions. The tea processor records the tea according to the different processing procedures, and the distributor records the storage of the stock. Their internal processes are isolated from each other, and the traceability information records are linked through transactions in the core network.

2.2.3 Core Network

The core network consists of block chain module, identity authentication module, license issuing module and public network access module. Blockchain can be thought of as a distributed database, with its immutable and traceable nature to ensure the persistence of the recorded data injected by the business layer and the transaction reliability of the traceability product flow. Smart contracts provide interfaces for the business layer and application layer to create, change and query traceability data. The module of identity authentication and license issuance is set up to limit the access of business layer, so as to provide authentication service for the licensed food supply chain service nodes. The access module of the public network connects to the Internet via some service nodes of the open core network in order to provide a service query without authentication.

2.2.4 Application Layer

Different from the traditional system architecture design, the FHCTS application layer is directly connected to the core network. The application layer provides data services based on service objects, including health code management, consumer user access, side access monitoring and hazard release, and data analysis and processing modules. The supervisory side mainly provides a clearance input for supervisory departments and laboratory for the food epidemic survey. The intelligent contract of the core network provides the interface and the application layer provides account and form management. Data analysis processing is mainly used for early warning analysis of detection and traceability products as well as basic analysis to support the health code.

2.2.5 Food Health Code

In the process of preventing, controlling and eliminating the dangers of food quality and safety incidents, we propose a model of the Food Health.

Code based on the reference model. Figure 2 shows the structure of the Food Health Code.

The Food Health Code consists of parts A, B and S. including:

Section A is the food traceability code. The first two bytes of data is consist of 16-bit big unsigned integers that represent the length of the contents of section A. The components of the latter part include the unit of production, the product type, the traceability batch, and so on. And:

- The first part is the food traceability code: the first 7 to 10 digits of the traceability code are the manufacturer's identification code. This part represents food production

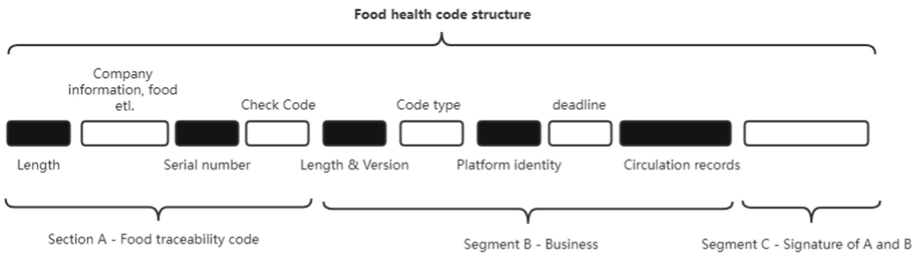

Fig. 2. Food Health code.

and processing enterprise information, food label number, approval document number and other information for product identification.

- The second part is the serial number of an individual product, and the production process is individually adapted by the manufacturer. The third part is the check bit: contains four check bits to check the correctness of the trace code.

Segment B is the business data representing the code type, code platform identifier, code expiration time and block hash value.

- The first two bytes are the length and the last two bytes are the version. The second part is the type declaration of the code, with four letters or numbers.
- The third part is the production site area code, and the fourth part is the current timestamp.
- The fifth part is the summary of the data sets for the traceability of foodstuffs by querying and encrypting the block data sets of the core network.

Section S is the digital signature value of A + B, and the signature authentication service is provided by the service node.

The essence of food health code is to calculate health anomalies by invoking the health engine at the application layer which is accumulated the health anomalies of batches according to the non-health feedback of the feedback pool and the control information released by the supervision side. The system set three levels of thresholds: green code-pass, yellow code-warning, red code-stop. When the outlier exceeds the threshold, the data analysis module will automatically notify the monitoring node and the detection node according to the convention. When the outliers are added to the red code, the related digital assets cannot be traded normally.

3 Results and Discussion

After adjusting the framework of the traceability system and adding the food health code engine, consumers can scan directly to identify food safety risks. The core network will isolate the production and dissemination links from external transactions, thereby reducing corporate dissemination data disclosure. According to the risk data model [7].

$$R = W \times S \tag{1}$$

W stands for the probability of occurrence of damage and S for the expected degree of damage. The system provides direct risk assessment for all types of direct food contact and can prompt them to take product-related risks when food safety incidents occur. Effectively reduce the likelihood and degree of damage, and then reduce the food safety risk.

At present, the traceability platform is not active enough, resulting in low commercial participation and low frequency of consumer use. FHCTS has reformed its practicality and risk communication skills. FHCTS uses a decentralized supply chain to connect the food traceability chain in a free market alliance, increasing the flexibility of enterprises to participate in traceability and the intensity of data protection. The second is to introduce a health code mechanism to improve consumer risk screening capabilities.

Comparison between traceability systems as shown in Table 1. Compared to traditional centralized traceability systems [18], FHCTS inherits the advantages of a decentralized traceability system and can avoid trust problems due to centralization. Second, compared with the current mainstream blockchain traceability system [2, 12, 17], it greatly protects the upstream and downstream associated data of enterprises, thus reducing business risks. In addition, the establishment of a traceability chain reduces the cost of building the traceability system, especially the traceability system for foods with a single category [9, 10]. Health code mechanisms can spread risks to users exposed to related foods faster than food warning systems (Wang, 2016).

Table 1. COMPARISON BETWEEN TRACEABILITY SYSTEMS.

Comparison of dimensions	Traceability systems				
	FHCTS	Traditional centralized traceability systems	Blockchain based traceability system	Food safety early warning system	Single category food traceability system
The cost of System construction	medium	low	high	high	high
degree of freedom	high	high	medium	low	low
risk management	high	low	medium	medium	medium
Privacy protection	medium	high	low	low	low
transparency	medium	low	high	high	high
Processing efficiency	high	high	low	medium	Medium

Due to the use of discretization to establish the traceability chain, there is an incomplete food information chain in the system. Therefore, in the future, an incentive mechanism should be introduced in the process of improving FHCTS to encourage the creation of a more complete traceability chain.

4 Conclusions

In general, this paper proposes a new traceability model and system to reduce the risk of enterprise exposure to circulation data and improve the risk perception of food consumers. On the premise of ensuring the reliability of traceability data with the use of blockchain and smart contracts, the Food Health Code traceability system can alleviate the pressure of supervision resources scarcity by maintaining a health state pool by multiple parties. And in the case of a problem product, it can prevent the second injury caused by the identified problem product in time.

The traceability chain is reconstructed by discretizing the relationship of the food supply chain, which improves the freedom of the combination between individuals and reduces the cost of traceability connection. Consumers prefer food with clear traceability [16], but food information chains with incomplete traceability process still exist in the system, so incentive mechanisms need to be introduced to stimulate the generation of more complete traceability chains.

References

1. Ahmad A, Bailey K (2021) Blockchain in food traceability: a systematic literature review. In 2021 32nd Irish signals and systems conference (ISSC)
2. Andoni M et al (2019) Blockchain technology in the energy sector: a systematic review of challenges and opportunities. Renew Sustain Energy Rev 100:143–174
3. Aung MM, Chang YS (2014) Traceability in a food supply chain: safety and quality perspectives. Food Control 39:172–184
4. Behnke K, Janssen M (2020) Boundary conditions for traceability in food supply chains using blockchain technology. Int J Inf Manag 52:101969
5. Dabbene F, Gay P (2011) Food traceability systems: performance evaluation and optimization. Comput Electron Agric 75(1):139–146
6. Feng H, Wang X, Duan Y, Zhang J, Zhang X (2020) Applying blockchain technology to improve agri-food traceability: a review of development methods, benefits and challenges. J Clean Prod 260:121031
7. Hampel J (2006) Different concepts of risk – a challenge for risk communication. Int J Med Microbiol 296:5–10
8. Hao Z, Mao D, Zhang B, Zuo M, Zhao Z (2020) A novel visual analysis method of food safety risk traceability based on blockchain. Int J Environ Res Public Health 17(7):2300
9. Liao Y, Ke X (2019) Traceability system of agricultural product based on block-chain and application in tea quality safety management. J Phys Conf Ser 1288(1):012062
10. Lin J et al (2018) Blockchain and IoT based food traceability for smart agriculture. In Proceedings of the 3rd international conference on crowd science and engineering - ICCSE18
11. Saberi S et al (2018) Blockchain technology and its relationships to sustainable supply chain management. Int J Prod Res 57(7):2117–2135

12. Sikorski JJ et al (2017) Blockchain technology in the chemical industry: machine-to-machine electricity market. Appl Energy 195:234–246
13. Tian F (2017) A supply chain traceability system for food safety based on HACCP, blockchain & Internet of things. In 2017 International Conference on Service Systems and Service Management
14. Wang J, Yue H (2017) Food safety pre-warning system based on data mining for a sustainable food supply chain. J Food Control 73:223–229
15. Wu Y, Liu P, Chen J (2018) Food safety risk assessment in China: past, present and future. J Food Control 90:212–221
16. Wu L et al (2015) Chinese consumers' preferences and willingness to pay for traceable food quality and safety attributes: the case of pork. China Econ Rev 35:121–136
17. Yong B et al (2020) An intelligent blockchain-based system for safe vaccine supply and supervision. Int J Inf Manag 52:102024
18. Yun Y, Kun W (2015) The key technology research of quality and safety traceability systems of agricultural products. In 2015 International conference on intelligent transportation, big data and smart city
19. Zhang Z, Godefroy SB, Lyu H, Sun B, Fan Y (2018) Transformation of Chinas food safety standard setting system – review of 50 years of change, opportunities and challenges ahead. J Food Control 93:106–111