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Blockchain-based System for Food Traceability

Yirui Qian[1], Cheng Zhang[2], Chengtao Luo[3], Hanyou Zhang[4], Liuqi Wang[5]

[1]Nanjing University of Posts and Telecommunications, Nanjing, 210023, China.

[2]Hangzhou Foreign Languages School, Hangzhou, 310023, China.

[3]University of Nottingham, Ningbo, 315100, China.

[4]Xiamen University Malaysia, Selangor, 43900, Malaysia.

[5]Wenzhou Kean University, Wenzhou, 325000, China.

Abstract

Food traceability technology has been one of the most popular directions of blockchain applications in the last years, not only because of blockchain becoming popular but also due to the increase of people's safety consciousness. This paper firstly elaborate on the business module and its work patterns with the Internet of things, which aims to decide what and how the parameters need to be collected. It is obvious that the existing food traceability systems cannot support a high standard of system transparency and reliability, which could certainly be improved by blockchain. Meanwhile, time-consuming is another problem, which means just inserting blockchain into the system without considering the efficiency and cost would not be a good choice. To develop a system that could adapt to the needs for food traceability, not for the digital currency, a new consensus mechanism was elaborately designed. Subsequently, an evaluation system would be built to assess if the food has decayed according to the parameters like the concentration of microorganisms, heavy metal, and additive.

Keywords

Blockchain, food traceability, food evaluation.

1. INTRODUCTION

In the 21st century, though the technology for food detection has developed to a high degree compared to the past, many difficulties still have not been handled [1]. Several cases about food safety happened in the food products, such as H1N1, mad cow disease, and so on [2]. For recent years, people's awareness of food safety has been increasing, and the shortages of existing food chain systems have been discovered increasingly. Under the circumstances, transparency and reliability become more crucial, which means a set level of transparency needs to be provided in the food chain [3]. This research is aimed to handle this problem, and blockchain is the tool to realize these functions.

Blockchain is a totally transparent system, which means everyone, even if he is not the constructor of the block, could see all the data recorded in the block system. The farmers, the processors, the warehouse managers, the sellers, and the consumers could see the entire information. Meanwhile, blockchain has another characteristic: immutability. All the data are only allowed to be added into the block, and no one has the authority to delete or change the finished transactions, which obviously guarantees the reliability of the data.

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2. BUSINESS MODULE OF FOOD TRACEABILITY SYSTEM

Having considered the difficulty of realizing food traceability described in the Introduction section, this part proposes a complete process of business module for this traceability system. The target is to provide module support for the construction of the food traceability system, monitoring the living condition, and collecting the needed parameters in the food's whole lifecycle and tracing through the process from the field to the consumers.

For this research, the object of the study is strawberry. Concerning the food chain, kinds of phases of the product lifecycle would be identified, which are shown below as graphs.

To begin with, the procedure could be generally divided into seven phases, which are shown in Fig.1.

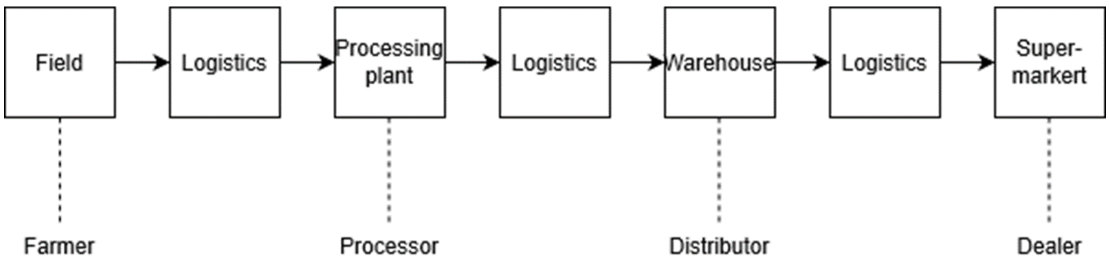

Figure 1. The food chain

Besides, the whole activities are exhibited in the Fig.2. There is one more thing to pay attention that the key parts of this research are the cultivation in the field and the logistics from the field to the processing plant. As to other parts, because the target products have not been decided, which will not be discussed in detail. For example, if the producer want to produce strawberry juice or dried strawberry fruits, or just sell the strawberry as fresh fruit, the storage environments will be different, and different kinds of data needs to be collected.

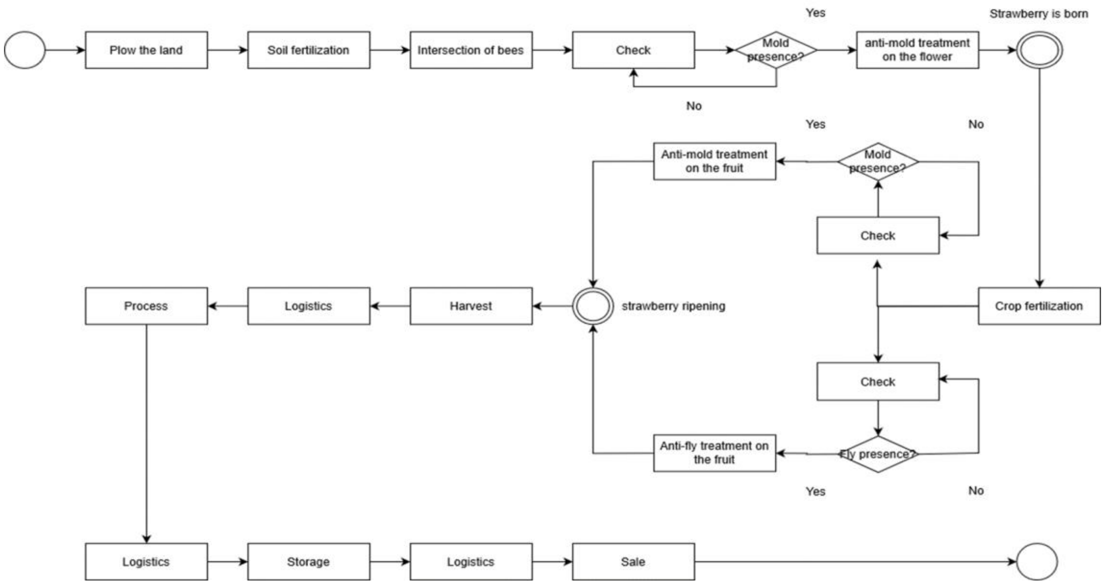

Figure 2. The cultivation-based food chain

To collect the requisite parameters during the complete business module, several factors need to be identified, which are as followed:

*The activities where the data about the food chain will be created;

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*The parameters need to be collected in these activities;

*How to collect the data;

Table.1 describes the activities, parameters, and the collection methods in detail. The cultivation of strawberries is the core objective of the research. The data needed and the collection methods are determined. Meanwhile, the parts of which the products are transferred out of the field have not been determined clearly due to the current situation.

Table 1. Details of activities, information and collection method

Activity	Information	Collection method
Plow the land	Field size	Manual Data Entry
	Field position	Manual Data Entry
	Number of trees	Manual Data Entry
	Type of trees	Manual Data Entry
	Chemical composition of the soil	Automatically collection by sensors
	Time duration	Manual Data Entry
	Description	Manual Data Entry
	Date	Automatically collection
Soil fertilization	Substance	Manual Data Entry
	Quality distributed	Automatically collection by sensors
	Description	Manual Data Entry
	Date	Automatically collection
Intersection of bees	Number of bees	Automatically collection by sensors
	Type of bees	Manual Data Entry
	Description	Manual Data Entry
	Date	Automatically collection
Anti-mold treatment on the flower	Substance	Manual Data Entry
	Quality distributed	Manual Data Entry
	Description	Manual Data Entry
	Date	Automatically collection
Crop fertilization	Substance	Manual Data Entry
	Quality distributed	Manual Data Entry
	Percentage in the soil	Automatically collection by sensors
	Description	Manual Data Entry
	Date	Automatically collection
Anti-mold treatment on the fruit	Substance	Manual Data Entry
	Quantity distributed	Manual Data Entry
	Description	Manual Data Entry
	Date	Automatically collection
Anti-fly treatment on the fruit	Substance	Manual Data Entry
	Quantity distributed	Manual Data Entry
	Description	Manual Data Entry
	Date	Automatically collection
Logistics from field to processing plant	Temperature	Automatically collection by sensors
	Humidity	Automatically collection by sensors
	Chemical composition of the gases	Automatically collection by sensors
	Description	Manual data entry
	Date	Automatically collection
Storage & Sale	Microorganism	Automatically collection by sensors
	Heavy metal	Automatically collection by sensors
	Additive	Automatically collection by sensors

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3. PROBLEMS OF FOOD TRACEABILITY

Figure 3. Food chain

Fig.3 shows a simplified version of the business procedure of food chain, and challenges are encountered for each part.

(a) Peasantries need to guarantee the safety and reliability of the critical information of origin material, including product introduction, date checking, and inventory.

(b) Manufacturers need to ensure the safety of products, the safety of sending and receiving products.

(c) Retailers need to detect whether the product is integrated and enable to visualize the delivery process of the product.

(d) For consumers, adequate trust in the information of product packaging, recognizing the product fast, and eliminating doubtful products if necessary.

Furthermore, three pain points of food traceability are concluded.

First, because the issue of traceability of commodities may have to be traced forward, it is proper to be able to record the production environment of the commodity. In the case of agricultural products, it is even necessary to record the key details of the production process, such as the application of pesticides and the problem of precipitation and drought. If these data can be recorded truthfully, it will help increase the credibility of the goods. In addition, not only the data on logistics but also more information needs to be entered, such as the information that the commodity flows in the entire supply chain, which will inevitably allow consumers to see the complete participant data, so as to add more trust on the endorsement subject.

Second, for the description in the first pain point, great quantities of information records are in a single system. If the information system is centralized, a problem that a single individual commits evil may occur, which means that if the project is led by Company A in the supply chain, the information of many links is included in the information system database provided by Company A. The data may be subject to hacker attacks, leading to data loss and damage. At the same time, because the system is centralized, there may be the possibility of artificially modifying the data, this in turn threatens the authenticity of the entire data.

Third, the current mainstream system has information island problems in the entire commodity supply chain. Generally, multiple information systems are in the entire supply chain, and it is difficult to interact with information systems, resulting in cumbersome information verification and unbalanced data interaction. Finally, too much offline verification and repeated checks are required to make up for the interaction of multiple system problems. In addition, the cost of repeated audits due to payment and billing issues is particularly high.

Based on the above three pain points and similar problems encountered in the field of commodity circulation, it is naturally suitable for the blockchain to solve. Before introducing the help of blockchain offers, the concepts of blockchain should be dedicated first.

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4. DIFFERENT VERSIONS OF BLOCKCHAIN

In November 2008, when a thesis had been posted by Nakamoto on a US mailing list, blockchain has developed for over ten years and iterated out three versions, which are blockchain 1.0, 2.0 and 3.0 respectively.

4.1. Blockchain 1.0: Bitcoin

Blockchain 1.0, represented by bitcoin, is a currency blockchain. The thesis that posted by Nakamoto titled "Bitcoin: A peer-to-peer electronic cash system," presented the following characteristics of this protocol:

1. Enables transaction directly with no need of any trusted third party
2. Enables the non-reversible transactions
3. Decreases credit cost in minor casual transactions
4. Decreases transaction fees
5. Prevents double-spending

Bitcoin, as a new version of currency, proposes and implements the concept of decentralization using the technology of hashing function, public key and secret key. Its basic structure is displaced as Fig.4.

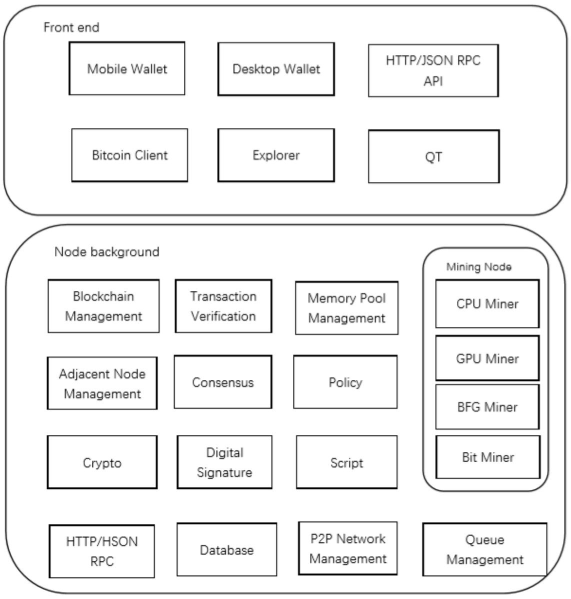

Figure 4. Basic structure of bitcoin

Compared with fiat currency, Bitcoin does not have a centralized issuer; instead, it is generated by the calculation of network nodes. Any individual can mine, buy, sell, or receive Bitcoin anonymously, which can be circulated worldwide on any computer connected to the Internet. However, as the initial state of blockchain, Bitcoin at that time is just a form of digital currency that achieves decentralization. It works like any other currencies in terms of payment, circulation, and other monetary functions. No additional operations could be carried out.

4.2. Blockchain 2.0: Ethereum

The contract blockchain technology represented by Ethereum is 2.0. Compared to Bitcoin, which stand for blockchain 1.0, the most upgraded segment is the participant of the smart contract. In summarize, Ethereum is the combination of digital currency and smart contract.

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Smart contract is a concept proposed by Nick Saab in the 1990s, which is almost as old as the Internet. Due to the lack of a credible execution environment, smart contracts have not been applied to the industry. Since the birth of Bitcoin, it has been recognized that the underlying technology Bitcoin can naturally provide a credible execution environment for smart contracts. The smart contract refers to a series of commitments defined in digital form, including agreements on which contract participants can execute these commitments. Once the smart contract is set up and designated, it can be automatically executed without the involvement of an intermediary, and no one can prevent its operation. Simply put, contracts established through a smart contract has two functions at the same time: one is a realistically generated contract, the other is a decentralized, impartial, and omnipotent executor who does not rely on a third party.

Moreover, the currency of Ethereum is updated to Ether. With the participant of smart contracts, blockchain 2.0 records and transfers complex asset types through smart contracts and smart assets. Bringing blockchain technology to a wider range of financial scenarios, such as crowdfunding and stocks, can be upgraded by transferring to the chain. Coupled with the blockchain decentralized ledger function, it is used to register, confirm, and transfer different types of assets and contracts.

The emergence of blockchain 2.0 has subverted individuals' perceptions of various financial industries and has epoch-making significance for the future development of the financial industry. So far, although the blockchain increases the working field of blockchain, it is still confined within the economic field and cannot implement an application.

4.3. Blockchain 3.0: Beyond the Scope of Currency and Finance

Blockchain 3.0, different from the past versions, becomes the platform of the application and penetrates into all walks of life with the participation of IoT and cloud service. Fig.5 displays its structure.

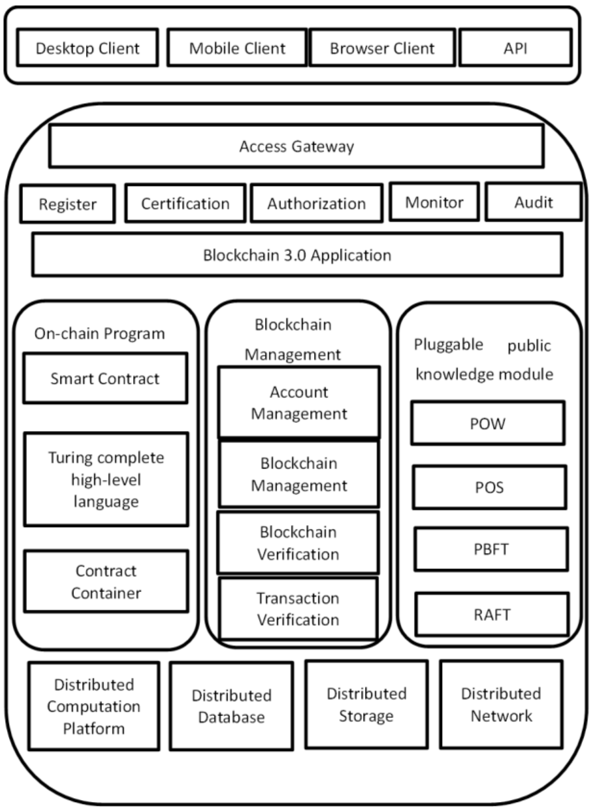

Figure 5. Basic structure of Blockchian 3.0

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The biggest change in Blockchain 3.0 is the introduction of the token economy. It has epoch-making significance because it allows the concept of blockchain to sink into the underlying technology, using tokens to connect the real business society and the real economy. It is also a fulcrum to pry the world. “Token” has five attributes: usability, convertibility, identifiability, tamper-proof, and technical consensus. On top of the problems solved by blockchain 1.0 and 2.0, Token also gives each participant in the industrial chain more authority and value.

One typical example of blockchain is Hyperledger, which is an open-source blockchain platform, founded in 2015 by Linux, to support the blockchain-based distributed ledgers. The protocol focuses on ledger development to support international business transactions and supply chain businesses, improving their performance and enhancing reliability. The project emphasizes on making collaborative efforts for making open standards and protocols, by offering a modular framework that backs various components for diverse uses, providing a range of blockchains with their own storage and consensus models, and the services for access control, contracts, and identity.

For the problem that food traceability is mentioned above, blockchain is able to solve that.

First, blockchain can keep record of every item in the supply chain system and support the supervision of the food products. The way the information generated in the blockchain is by packing the data into blocks and adding timestamps to form a chain. Such a process is similar to the way a supply chain gets generated, so the two can be integrated. A product will enter the chain according to the chronological order: from raw materials, processing, quarantine, to transportation, storage, shelf sales, a complete process record will be generated.

Second, the information on the chain cannot be tampered with. Once the information is on the chain, it cannot be erased, which is a characteristic of decentralization.

Third, it increases credit endorsement. As mentioned above, far more than one party is in blockchain’s information record, so they can supervise each other, and it increases the risk and difficulty of fraud.

Fourth, adopting blockchain reduces the cost of building the supply chain. Blockchain can be used as a general ledger, a unified certificate for the whole supply chain, optimizing the supply chain, and reducing unnecessary verification, thus improve efficiency.

Fifth, better clarify responsibilities and strengthen credit filing. Because of the real-time record of the blockchain and the non-modified, open and transparent characteristics, once a problem occurs in a link, it is easy to find out which step has the problem and who the responsible person in this link is. At this time, there will no longer be the problem of pushing out "temporary workers" to blame the crime, reappearing again and again to re-operate in the old profession, because if this person ever falsified, in this system, consumers can fully see and Smart contracts can be set up to automatically alert hidden safety hazards.

The sixth is to prevent counterfeit goods effectively. The product's information on the entire process is on the chain, which is equivalent to giving the product an identity card. No matter where it appears, its identity can be confirmed. At this time, it will significantly increase the difficulty if the fake replaces the good product.

5. GENERAL STRUCTURE: FROM IOT TO BLOCKCHAIN

This section designs a blockchain-IoT based food traceability system to describe the relationship between IoT and blockchain in this system, namely, how IoT interacts with blockchain by the database, demonstrated by Fig.6. The data are first collected by IoT, then transferred into the database, and eventually built into the blockchains.

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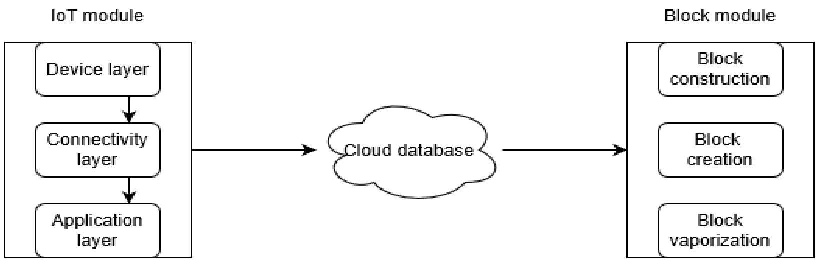

Figure 6. How IoT interacts with blockchain by the database

Before that, the process of the IoT needs to be identified clearly, as shown in Fig.7. Broadly speaking, IoT technology could be divided into three main components: device layer, connectivity layer, and application layer. The device layer is aimed to collect data. In the device layer, the sensors and relay nodes consist of this level to collect data from environments. The connectivity layer aims to transmit data. In this layer, transmissions between the sensor nodes and relay nodes are operated by Bluetooth, while transmissions between the relay nodes and IoT platforms are operated by machine-to-machine technology. The application layer, such as IBM Cloud, aims to manage data. Next, the data are transmitted into the database. Finally, the collected data are used to calculate the food shelf life and check if the food has decayed.

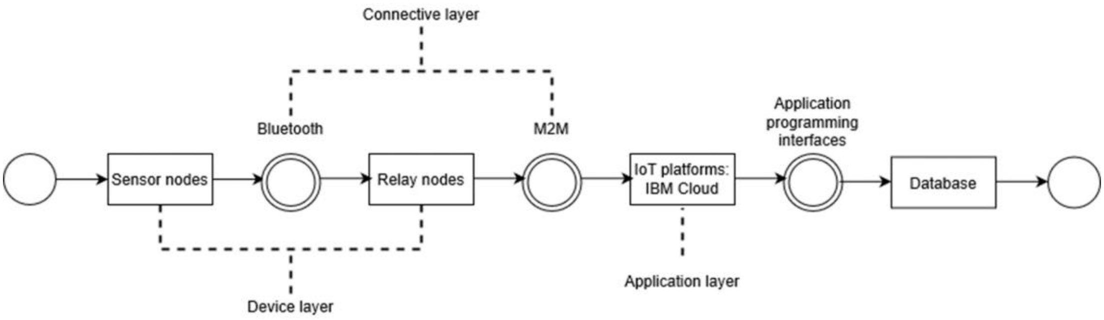

Figure 7. The process of the IoT

Now, the simple figure below could clearly discuss the relationship between the data and the blockchain. In Fig.8, it is clear to see that as the blocks keep being created, the data of the rest of the food chain are recorded in the corresponding blocks in order.

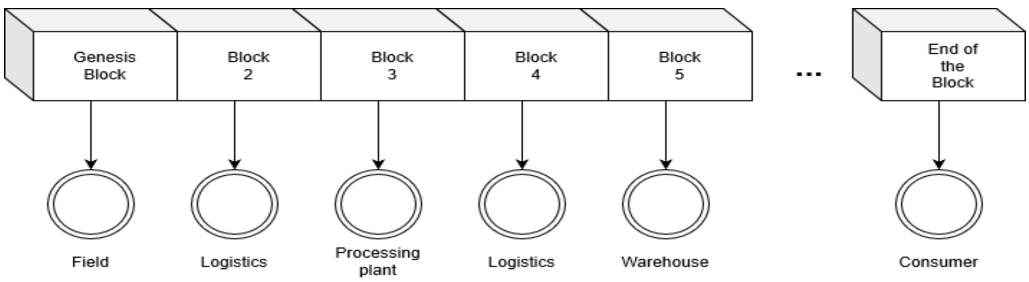

Figure 8. The relationship between the data and the blockchain

6. IMPROVEMENTS OF BLOCKCHAIN

The popular blockchain architecture doesn't fit with the demands of food traceability very well while carrying real-time data collection and efficient perishable food supply chain data management [4]-[7]. As so, some apposite modifications are implemented in blockchain deployment to bring more efficient executions and less unnecessary consumption, and at the

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same time, the merits of typical blockchain are exploited adequately, especially like decentralized control, distributed data entity, non-repudiation, high security, auditability, and data transparency.

At first, to achieve proof of work, there is a huge demand for resources, and long delays scheme is implemented to solve the double-spend problem (which is not a problem for food traceability at all) [8,9]. In the food traceability system, real-time data from multiple units following the food supply chain are stored in the blockchain continuously, so it's very inefficient for mining and forging new blocks. In cryptocurrency, the proof of stake is proposed against the aforementioned problem, which is accomplished by choosing the person who forges the new block according to different selection standards, like how many coins the person owns.

For food traceability system, this work propose a new consensus mechanism, proof of evaluation (PoE), which imitates the proof of stake. In such a mechanism, validators are going to forge a new block into the blockchain, in which the validator will be one of the stakeholders of some units along the supply chain. The evaluation value (Ei) is used to decide who will be the next one to forge a new block, as shown in Equation (1), where i represents an index of some stakeholder.

$$E_i = T_i * P_i$$

Equation (1)

The total number of stakeholders is N. There are m sections (stages or operation units) along the perishable food traceability chain and assume the total time spent in all sections is T. Every section is charged by a specific party or a specific stakeholder. As so, Ti is the ratio of how much time the ith stakeholder spends in the whole food supply chain to the total time T as follows:

$$T_i = \frac{1}{T} * \sum_{j=1}^{m} t_{ij}$$

Equation (2)

Where ith stakeholder takes t_{ij} to carry out the task of jth section.

Nevertheless, the transit time should not be the only criteria to consider about because there may exist a stakeholder carrying the food for a relatively long time but who is not the one that desires to contribute more to the food traceability system or the one that has the potential of creating more benefits for the food traceability system. Thus, four main factors are added to analyze and measure each food supply chain stakeholder[10,11]:

Resistance factor R: represents the ability to withstand emergencies, take control of the whole situation, contain the crisis from deterioration, and recover damages when some abrupt accidents happen. According to the result of the analysis, we can give R with a discrete range from one to five.

Scale factor S: describes the influence of a party in the food supply chain. It also represents the ability to attract more stakeholders to the system or the ability to promote the system. It can be ranged from one to five based on the party's market share or the number of basic users.

Devotion factor D: shows the interest of stakeholders in the food traceability system and the extent of how many resources the stakeholder wants to share. There will be five levels from one to five, respectively mapping to different thresholds their shared resources reached.

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Return on investment I: defines the ratio of return value (from food traceability system, including direct income and indirect income) to the cost of investment on the system. It also can be divided into five levels by setting five thresholds.

The weighting coefficient σ is set to an appropriate value between 0 and 1 to determine a prone strategy in terms of scale factor and devotion factor. Therefore, the stakeholder analysis part of proof of evaluation is as follows:

$$P_i = \frac{R_i * I_i * [\sigma * S_i + (1 - \sigma) * D_i]}{P_{sum}}$$

Equation (3)

Pi is defined as the weight of the sum of all stakeholder analysis result values that is Psum. The weighting coefficient σ decides three different strategies for choosing the creator of new blocks:

σ = 0.5: moderate strategy

σ = 0.8: scale-first strategy

σ = 0.2: devotion-first strategy

The purpose of implementing those four factors in the analysis of stakeholders is to enhance the equity and comprehensiveness of the food traceability system's consensus mechanism, and as a result, the transit time is not the only determinant. The combination of stakeholder analysis and transit-time factors accomplish a more effective description and representation for each stake value of each stakeholder party along the whole perishable food supply chain. Moreover, the PoE consensus mechanism brings a similar effect as PoS in digital currency to choose a validator for block creation in food traceability blockchain.

Secondarily, in daily life, a food supply chain includes a diversity of activities and corresponding units to deal with them. It's obvious that there are all kinds of information needed to be recorded like the farm producing raw material, a variety of production date and exact time, the transit sites, and so on. However, it is not feasible to record all these data into the blockchain of the food traceability system, which will cost tremendous memory storage and reduce efficiency [12, 13].

In the food traceability system, the blockchain module interacts with the IoT module actively. Meanwhile, cloud computing technologies also play an important role in this system. Together they construct the foundation of the food traceability system. Specifically, the real-time IoT module interactions are stored in a cloud database instead of recording all information into the blockchain. Then IoT will assign an index ID for every data list as well as event and IDs are recorded into the blockchain, and as a result, every product is associated with real-time information collected from the IoT module. As a result, it is viable to achieve lightweight data blocks and concise blockchain applications, so that the blockchain only process minimum data to optimize flexibility and adaptability of the food traceability system. When a consumer submits the perishable food order in some electronic commerce platform, the smart contract will work to send a thank-you message and provide authority to access related food traceability records.

Thirdly, a definite endpoint of blocks in the blockchain module should be set in most relevant applications. As a result, the vaporization characteristics of blockchain is proposed.

In terms of the perishable food life cycle in the food supply chain, the duration of blocks and the length of the blockchain can be specified by setting definite start points and endpoints. Blockchain architecture in the food traceability system is not necessary to carry all related

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records that are different from in the cryptocurrency, which may bring a hard burden on memory storage and cause a negative effect on the efficiency of execution. Thus, the vaporization mechanism of the blockchain module is developed for accomplishing food traceability more efficiently and making the system more reliable. From the beginning of the supply chain, food raw materials are supplied by farms and further processed by food factories or primary process plants, and in such a way, the genesis block is created while farm ID can be distributed to the raw food material. With the further transmission of food products, the continuous change of environmental conditions and events happened will be collected and stored into the cloud database and blockchain. Along the food supply chain, the factory ID, port ID, and distributor ID are recorded to identify and trace the specific food products. After reaching some ending points like the finish of delivery activities, signal of customer confirmation, or point of sales, specific blocks in the blockchain are then vaporized to release memory and storage space in the system. Meanwhile, the vaporized parts of blockchain are transferred to the cloud database.

7. AN AVAILABLE FOOD EVALUATION SYSTEM [14]-[17]

The available food evaluation system is one of the important contents of food traceability. Only by establishing a sound food safety assessment system can food safety be guaranteed by a reliable system. In order to establish an effective food evaluation system, we need to go through three steps.

1. Collect parameters
2. Analysis parameters
3. Draw Conclusion

7.1. Collect Parameters

Parameter selection is one of the important steps of the food evaluation system. Because under the condition of limited resources, we must select the most appropriate parameters to evaluate food. This parameter must be typical and scientific. No matter which method is selected, the data, time, and other resources consumed by the method should be fully considered to match the evaluation purpose. It is not allowed to blindly pursue the accuracy of the results or excessively consume resources in order to pursue the closest to the actual situation.

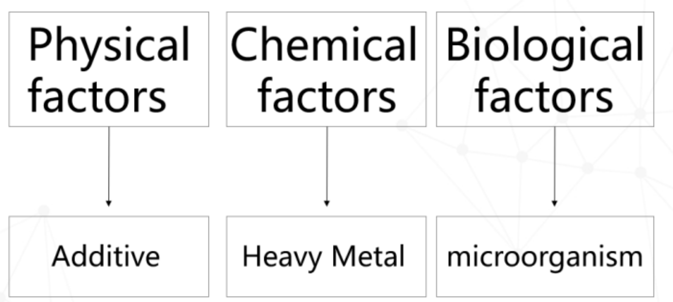

Figure 9. The relationship between different factors and their representative substances

Generally speaking, the factors that can hurt human health in food can be divided into physical, chemical, and biological factors. There are three kinds of food, which can be divided into microorganisms, heavy metal, and additive. Therefore, we analyze the above three indicators. It can be classified as additive, heavy metal, and microorganism in the index of food sampling, which is shown in Fig.9.

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In order to explore the impact of microorganism, heavy metal and additives on the safety of main food fields, we can count the unqualified rate of each index in different fields according to the sampling situation, and then analyze which index has the greatest impact on food safety, so as to select the most suitable parameter. Next, we will give an example of how to select parameters.

Table 2. Content of over standard substances in main food fields. [17]

Food sector	Over standard substance	Over limit critical value	2012	2013	2014
Rice flour products	Microorganism(cfu/g)	750	3856	4079	3633
	Additive(g/kg)	0.075	0.183	0.489	0.422
Meat Products	microorganism (cfu/g)	30000	440000	140000	657750
	heavy metal(mg/kg)	0.2	5.95	8.75	3.15
	additive (g/kg)	0.075	0.1932	0.1505	0.139
Snacks	microorganism (cfu/g)	750	4267	3247	7500
	additive (g/kg)	0.35	0.367	0.526	0.46
Dried products	heavy metal(mg/kg)	0.2	7.6	2.23	5.03
	additive (g/kg)	0.1	0.499	0.328	0.487

Table 2 shows 2012 to 2014 over standard data of several indexes in four fields, which in Shen Zhen, China. We can analyze the data to try to explain how to select parameters. In this process, due to the strong randomness of the data and the small sample size, we need to use the grey theory. It is a method to measure the degree of correlation between factors according to the degree of similarity or difference of development trend among factors. It can be a good tool to help us clarify the relationship between food safety and pollutants.

First, set a = {a0, a1, a2, a3} is a set of grey correlation factors.

a0 is reference sequence, or we can call it food safety indicators.

a1, a2, a3 is comparison sequence, which equal to three indictors: microorganism, heavy metal, and additive.

So, ai(k)(k=1,2,3) is the k-th number of ai, namely

a0 = (a0(1), a 0(2), a0(3))

a1 = (a1(1), a 1(2), a1(3))

a2 = (a2(1), a 2(2), a2(3))

a3 = (a3(1), a 3(2), a3(3))

Then, calculate the correlation degree and analyze the advantage factors.

So, we need to use the formula to calculate the degree of correlation,

$$r0i\ (a0, ai) = \sum_{k=1}^{n} \rho ai(k) (i = 1,2,3; k = 1,2,3, \ldots, n; \rho = 0.5),$$

r0i (a0, ai) represents the grey correlation degree between a0 and ai.

Then we can get the correlation matrix R

R = [r1(1) r1(2) r1(3)]

R = [r2(1) r2(2) r2(3)]

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R = [r3(1) r3(2) r3(3)]
R = [r4(1) r4(2) r4(3)]

R shows the correlations between different comparison indexes and reference indexes in four kinds of food.

Then we can use the data in Fig.10 to calculate in MATLAB, so we can get the picture in Fig.10.

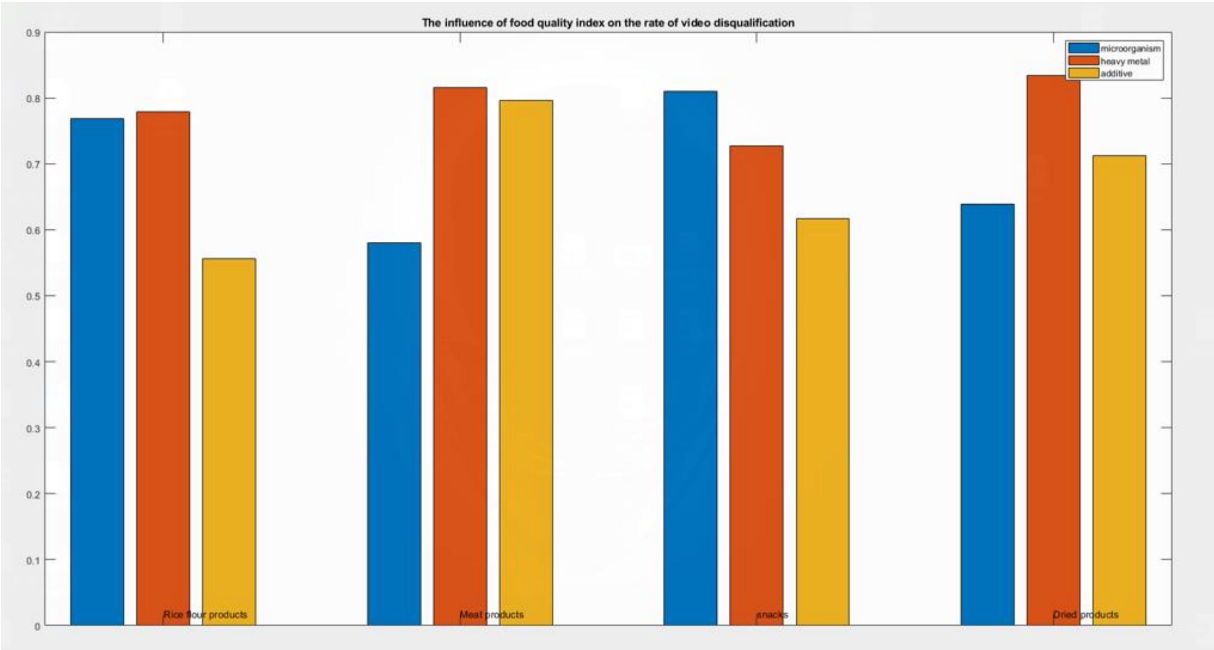

Figure 10. The influence of food quality index on the rate of video disqualification

In Fig.10 we can see:

For rice flour products, microorganisms and heavy metals have a greater impact, while additives have a relatively small impact.

For meat food, heavy metals and additives have a great influence on food safety.

For snack food, the microorganism is the most important factor, and additive is the least.

For dry products, heavy metals have a greater impact, while the other two effects are relatively light.

Obviously, heavy metals have a great influence on the safety of four kinds of food, so we can draw a conclusion that the heavy metals are the most suitable parameter we can collect.

7.2. Analysis Parameters

When we have selected the appropriate parameters, we must analyze the selected parameters. There are many kinds of heavy metals, such as cadmium, mercury, etc. We need to consult the relevant data of different regions to find out the impact of pollutants on food safety. For example, Table 3 shows the hazard index of food safety in different concentrations of pollutants.

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Table 3. The relationship between the concentration of pollutants and the Safety index.[16]

Name of chemical pollutant	concentration	Safety index
cadmium	0----0.0085 0.0085---0.0425 0.0425---0.085 >0.085	0----10 10----50 50----100 >100
mercury	0-----0.0028 0.0028----0.014 0.014-----0.028 >0.028	0----10 10----50 50----100 >100
arsenic	0-----0.057 0.057----0.285 0.285----0.57 >0.57	0----10 10----50 50----100 >100
Dichlorvos	0----0.018 0.018-----0.09 0.09----0.18 >0.18	0----10 10----50 50----100 >100

7.3. Draw Conclusion

The last step is to comparison with the hazard index classification of pollutants to food, such as Table 4. We can get whether the food is really safe and non-toxic.

Table 4. The corresponding relationship between the safety index and the degree of poisoning. [16]

Safety index	0-10	10-50	50-100	>100
Poisoning degree	Safe and nontoxic	Normal	Mild poisoning	poisoning

8. CONCLUSION

This work proposes a blockchain-based food traceability system to promote transparency, efficiency, and trust between parties involved in the perishable food transactions. A complete process of business module for this traceability system is designed; a new consensus mechanism (PoE), lightweight blockchain, and vaporization mechanism are put forward; an available food evaluation system is proposed and partly implemented.

Undoubtedly, food traceability ensures food quality and promotes food companies' reputation, thus attracts customers, which should be adopted widely. However, there are relatively few food companies that have adopted the blockchain to guarantee their food quality.

According to Mitchell Weinberg, who founded the food fraud detection and prevention firm Inscatech, there are two major impediments to blockchain food traceability adoption: The first is that it requires full participation from all parties and points of contact involved. The second is that it requires honest participation[18]. Namely, a unified system with definitive standards and regulations is of great importance. These two are the long-lasting barriers of blockchain adoption, and plausible solutions might come out in this decade. Nevertheless, there are other difficulties with blockchain adoption, and some solutions are proposed as follows.

In this competitive industry, it is reasonable that some parties are reluctant to share information. As an enterprise, it is not wise to provide all the data to the world, including some potential adversaries. Therefore, a possible future improvement for our blockchain food traceability system would be building a permission-based network. Participants (farmers, processors, especially the food companies) should have control over who can see their information and who cannot. Specifically, the customers are allowed to track the food items they

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bought; as for others who did not buy the food but need to check the information such as the food origins or detailed processing data, like the Food Administration, they will need their secret key to gain access to the information. Any check-the-info action will be recorded in the cloud database (blockchain is not needed since it does not require decentralization), enabling the food companies to supervise the tracking and tracing process and avoid unnecessary information leakage.

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