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A traceability method based on blockchain and internet of things

Xueying Dong, Xianghan Zheng, Xiaoliang Lu, Xiaowei Lin
(School of Mathematics and Computer, Fuzhou University)
(The National Key R&D Program of China under Grant No.2018YFB1004800)
Email:dxyers@hotmail.com

ABTRACT

With the rapid development of the social economy and the continuous improvement of people's quality of life, under the background of promoting "Internet +" modern agriculture, the safety of agricultural products has aroused widespread concern in society, and further promoted the research of traceability technology of reliable and credible agricultural products. This paper proposes a method that apply the Internet of Things and blockchain technology to agricultural traceability scenarios. The method uses agricultural sensors to detect product production environment parameters, improve production efficiency, and uses blockchain technology combined with asymmetric passwords to provide security for the Internet of Things. Blockchain technology makes data irreversible and traceable, which enables the traceability of agricultural products to be realized. This paper also proposes a fusion method of blockchain technology and intelligent technology. It uses machine learning methods to analyze the production and sales data on the chain, helping producers and enterprises to improve efficiency and solve practical problems.

Keywords: Internet of Things, blockchain, intelligent technology, agricultural traceability

1 Introduction

With the improvement of China's economic level, the quality of daily life of the people has also been continuously improved, and the concern for food safety is rising. At the same time, the government is also increasing its focus on food safety issues and promoting research on food traceability applications[1].

The Internet of things originated in the media field and is the third revolution in the information science and technology industry[2]. The Internet of Things is based on information carriers such as the Internet, broadcast television networks, and traditional telecommunications networks, allowing all common physical objects that can be independently addressed to be interconnected. Today, Internet of Things technology has been used in a large number of people's life production. Related research shows that by 2020, there will be more than 50 billion IoT devices in the world. The Internet of Things is quietly changing our lives, such as in smart homes, in-vehicle systems, transportation, and more. The application of Internet of Things technology has greatly improved the efficiency of people's production and life. In the future, IoT technology will find more applications in medical, agricultural, and defense systems.

The blockchain technology was proposed by Satoshi Nakamoto in 2008, "Bitcoin: A Peer-to-Peer Electronic Cash System" [3]. Since entering the public's field of vision in 2012, it has become one of the hottest network technologies. The blockchain has the characteristics of decentralization, traceability. These features can be applied in many application scenarios. In recent years, blockchain technology has experienced a blockchain 1.0 model (bitcoin) featuring a programmable digital cryptocurrency system, and a 2.0 model with a programmable financial system as its main feature[4]. In this paper, the Internet of Things and blockchain technology are applied to agricultural traceability scenarios. The Internet of Things is used to detect the growth environment of crops, and collect the growth information of crops. The blockchain platform obtains the health status of crops through data analysis and guides producers to plant. We use blockchain technology to provide security for the Internet of Things, making up for the security holes in traditional IoT. At the same time, the blockchain makes the production data complete and traceable, ensuring the safety of processed foods. Through the Internet of Things and the blockchain, the process of planting, processing, transporting and inspecting farm products is realized more safely and efficiently[5].

The remainder of this paper is organized as follows: Section 2 describes the existing traceability system. Section 3 details the architecture and implementation of the system. Section 4 is the experimental part. Section 5 summarizes this article and looks forward to the future work.

2 Related work

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Muangprathub et al[6]. proposed an intelligent planting system based on the Internet of Things, which improve planting efficiency through a combination of hardware, networking, and mobile devices. The article proposes to use a centralized control box device to control the sensors and irrigation equipment distributed in the farm. The control center analyzes the growth of the crops and analyzes the data in the cloud to arrive at the best irrigation plan. At the same time, producers can use the mobile end to manually adjust the planting plan. The results show that the method improves the efficiency of production and saves the energy of the producer. However, this method is still a centralized management method, and the producer has the right to modify the growth information of the crop. Bad businesses create information on the production of agricultural products in order to obtain benefits. The information obtained by the Internet of Things is not open and transparent, which makes it easy for lawless elements to take advantage of.

Xu et al[7]. proposed a traceability chain system based on blockchain technology, which applies the traceable characteristics of blockchain to the circulation review process of products, making the production and circulation process of products open and transparent. The article applies blockchain technology to open and transparent the product life cycle, which provides great convenience for the regulatory authorities, as well as long-term effective supervision of food safety. However, the method proposed in this paper lacks application examples. The application of blockchain technology is limited to the display level, and it should be possible to further integrate the application scenarios and take advantage of the blockchain.

Hammi et al[8] proposed a blockchain-based IoT distributed system. The system groups IoT devices through blockchain smart contracts. Devices can only exchange information within a group and cannot interact between groups. External devices cannot invade IoT devices. This method uses blockchain technology to provide security for the Internet of Things. However, excessive sealing also prevents the Internet of Things from communicating with the outside world, and the system is too occluded. Information cannot be effectively utilized by external systems.

In summary, the existing use of Internet of Things and blockchain technology in agricultural traceability products has some security problems or technical deficiencies. It is difficult to protect information security while giving full play to the advantages of open and transparent blockchain technology information. In view of the above improvements, this paper proposes a traceability scheme based on the Internet of Things and blockchain technology, which brings the advantages of efficient and convenient IoT and blockchain security. The specific method will be discussed in detail in the next chapter.

3 Proposed approach

3.1 System Architecture

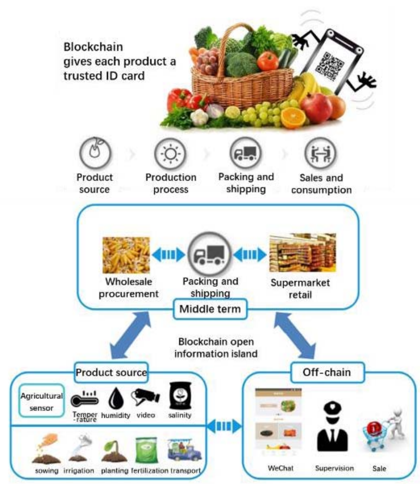


Figure 3-1 System Architecture

As shown in Figure 3-1. In the agricultural product supply chain, the source of the product, the production process, the packaging and transportation, and the consumer four parts will generate a lot of information. In the traditional supply chain system, they each save and manage the information data generated by their own links. The data obtained through other systems is stored in the centralized server, and does not enable other links to gain trust. Blockchain technology has got rid of traditional centralized servers. The data information in the supply chain will be stored in the blockchain platform, and the data will not be tampered with once it is stored. The system gives each agricultural product a unique "identity card" for data collection and transmission in all aspects of the supply chain. Figure 3-1 shows the architecture of the system. At the source of the product, the planting process, agricultural sensors that measure various environmental parameters, including humidity, temperature, and fertilizer concentration of the soil, are deployed. The hardware section also includes surveillance cameras to visualize the crop planting process, allowing system users to visually see the growth of agricultural products. This information is collected by sensors and uploaded to the blockchain platform. Each sensor uses public-private key encryption, as well as a time-random sequence to uniquely identify temporary IP, preventing impersonated pseudo IP from incorporating "dirty data."

After the crop growth information is uploaded to the blockchain platform within a certain period, it is packaged to generate a new block. The blockchain implements information integrity and security. This has greatly facilitated the work of the regulatory authorities. Crop growth information is provided to regulators for the identification of food safety and as a source of data analysis. The system uses intelligent technology to analyze crop growth information, dig out the intrinsic link between crop growth environment and growth status, and give recommendations to help producers better grow products. Combining smart technology with blockchain technology is also a bold attempt to be innovative. In the circulation, the product information is scanned by scanning the RFID code on its box. The circulation process includes information such as the origin, circulation path, and distribution of the product. This information will follow the product and be recorded on the blockchain platform. When consumers purchase products, they can get the information by scanning the QR code of the product.

3.2 Hardware Design

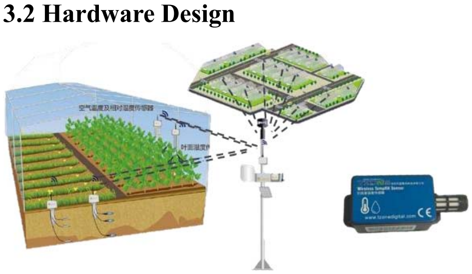


Figure 3-2 Internet of Things Architecture

The system sets a node every ten meters according to the terrain, and each node is connected to a sensor buried in the soil 25-35 cm deep[9]. These sensors measure a variety of soil properties such as temperature, volumetric moisture, salinity, and more. The sensor farm is covered by wireless and uses a remote wireless module. The sensor sends data to the control center every twenty minutes. The data center processes the data sent by the sensor based on the blockchain smart contract.

The specific components of the sensor are as follows:

Table 3-1 Agricultural sensor components

Module	Hardware model
core	STM32F103 normal power consumption microcontroller (for gateway nodes)
	STM32L051 low-power microcontroller (for sensor nodes)
sensor	Light intensity module GY-302
	Temperature and humidity module DHT11
	Soil moisture sensor FC-28
	Raindrop sensorFR-04

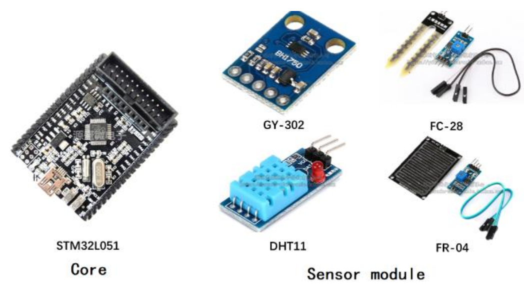


Figure 3-3 Agricultural sensor

The sensor device is powered by a battery, and its power consumption is low. Generally, it can maintain a service life of 1-2 years, and can continuously obtain information on the growth environment of agricultural products[10]. The use of sensors eliminates the inefficient labor of manpower. The data collected using sensors has great research value. In the next section, we will discuss the use of machine learning algorithms to mine the intrinsic link between sensor information and crop growth[11].

3.3 Blockchain and Intelligent Technology

3.3.1 Planting data intelligent algorithm

The large amount of agricultural data collected by sensors, in addition to ensuring the safety and credibility of agricultural products, has enormous internal value. It contains the relationship between crop growth and environmental factors[12]. A blockchain is essentially a distributed database. How to make good use of the data in the blockchain, how to combine the blockchain with the smart contract is also an important research direction of recent researchers[13].

In this paper, the apriori algorithm[14] is used to mine the information from the data. We abstract the planting scene into a linear regression model. In the planting scene, the temperature, humidity, soil salinity, etc. of the environment will affect the growth of the crop. However, in different scenarios, the environment required by the plant is different. To manually determine the appropriate environmental parameters requires years of planting experience. Through machine learning algorithms, we mine intrinsic correlations from large amounts of data to determine optimal environmental parameters. The linear regression model[15] is as follows:

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \ldots + + \alpha_n x_n + \xi \tag{3-1}$$

Where y is the output variable and x_i is the input variable, $i = 1,2,\ldots,n$. α_j is a coefficient based on x change, $j = 1,2,\ldots,n$. ξ is a random error. The Apriori algorithm is used to solve the coefficients of the linear regression model, so as to give appropriate environmental parameters and guide the producers to plant crops. We used the actual data of Putian Farm (Table 3 - actual part data) to calculate the environment and calculate the environmental model suitable for the cultivation of Camellia oil in Putian Farm as follows:

$$Prod\_camellia = 0.1 * Humidity + 0.88 * Temperature - 0.03 * Salinity - 16.54 \tag{3-2}$$

The calculation result is consistent with the actual growth environment and can provide effective help for the producer.

3.3.2 Sales Data Intelligent Algorithm

In production companies, middlemen, and consumers, business activities generate a lot of information and data. The sales of traditional agricultural products still stay at the stage of simply recording transaction information, and cannot integrate and aggregate various information, which has hysteresis and cannot predict market trends very well. Based on the blockchain platform, this paper uses the data collection and use to predict the future trading situation.

In the supply chain, data on the planting, processing, transportation, and sales processes of the product are written into the block. As shown in Figure 3-5, at the source of the product, data is uploaded to the blockchain platform through the Internet of Things. In the process of product circulation, the data is scanned by RFID technology[16], and the unique identification code of the product is scanned to upload the data to the platform. On the consumer side, the consumer's purchase record will be uploaded. These data, as well as seasonal weather and other factors, have a certain effect on predicting market trends. The traditional traceability method does not have the ability to collect data. The blockchain platform connects the entire supply chain in tandem, and every link in the supply chain has traces.

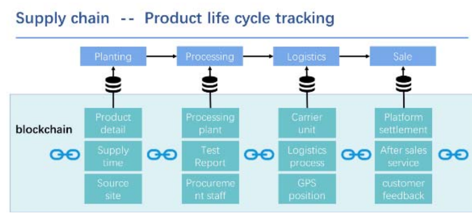


Fig.3-5 supply chain

The blockchain platform effectively uses this information to explore market trends, predict market demand, help producers control production, and assist companies in their external business. The various steps in the entire transaction process are counted by the blockchain, which improves the level of enterprise information and reduces costs.

For the market demand forecast of agricultural products, the H-P filtering method[17] is used in this paper. The H-P filtering method is an analysis method of time series in the state space, which is equivalent to minimizing the variance of the fluctuation. Assuming that the agricultural product sales sequence is $Y = \{Y(1), Y(2), \ldots, Y(n)\}$, the trend factor for agricultural product wholesale sales is $G = \{G(1), G(2), \ldots, G(n)\}$. Where n is the capacity of the sample. Therefore, H-P filtering can decompose $Y(t)$ into: $Y(t) = G(t) + C(t)$, where $G(t)$ is the trend component of product sales, and $C(t)$ is the fluctuation component, which is affected by various random interference factors. The paper uses the historical data of Wisdom Farm to analyze the market demand of the coming year by H-P filtering model, and obtain the trend value. The calculation formula of the H-P filtering method is as follows:

$$Y_{t+1} = Y_t + (Y_t - Y_{t-1}) + \sum[(Y_t - Y_{t-1}) + (Y_{t-1} - Y_{t-2})]/2 \tag{3-3}$$

Let $\varDelta Y_t = \sum[(Y_t - Y_{t-1}) + (Y_{t-1} - Y_{t-2})]/2$, then:

$$Y_{t+2} = Y_{t+1} + (Y_t - Y_{t-1}) + \sum[\Delta Y_t + \Delta Y_{t-1} + \Delta Y_{t-2}]/3 \qquad (3\text{-}4)$$

By analogy with $Y_{t+3}, Y_{t+4}, Y_{t+5}$ (the fixed growth difference plus the multi-step moving average of the quadratic difference), in order to test the accuracy of the formula, we use the 2008-2012 data to predict the market demand for 2013-2018. The final calculation results are shown in Table 3-2.

Table 3-2 Comparison of forecasted market demand and actual sales

Year	2014	2015	2016	2017	2018
Farm Product Sales (Tons)	3.82	4.32	3.62	5.55	5.23
H-P predicts market demand (10,000)	3.72	4.21	3.69	5.50	5.30
Deviation (%)	2.61	2.55	2.04	0.9	1.3

It can be seen that the trend of using the H-P filtering method to market demand is roughly consistent with the actual sales volume, and with the accumulation of data, the accuracy rate has been increasing year by year. For producers, being able to know the trends of the market in the coming year will help to arrange the scale of crop planting in advance.

3.4 Blockchain Security Algorithm

The hardware and equipment of the Internet of Things is simple in structure and does not have security modules, and is vulnerable to external attacks. Therefore, criminals often choose IoT devices to attack[18]. The common types of attacks are as follows:

1) Data source attack: Provides fake data to hardware devices. The attacker has control and write access to the hardware device, and the hardware needs to have a write interface.

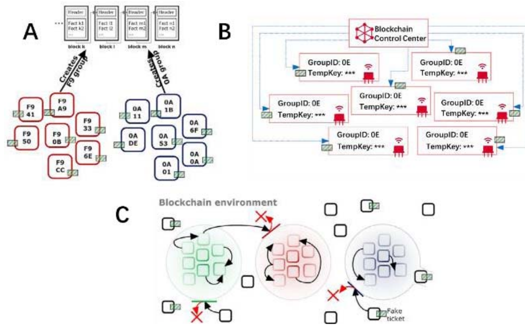
2) Message substitution attack: The attacker intercepts the data uploaded by the hardware device, replaces the original data with its own fake data, and sends it to the control center, or the attacker disguise itself as a hardware device and send data to the control center.

3) Delayed attack: The attacker intercepts the data uploaded by the hardware device and

does not send it to the control center. In a future cycle, the data is resent, causing the data information to be asymmetrical with the actual scene.

Fig.3-6 blockchain safety algorithm

In response to the above problems, this



paper uses a blockchain platform-based security algorithm to provide security for IoT hardware devices. As shown in Figure 3-6, the algorithm is as follows:

a. For each sensor device, the blockchain network uses an asymmetric cipher to generate a set of key pairs[19]. The public key is stored in a blockchain platform and the private key is written into the hardware device.

b. Every other period, initiated by the blockchain control center, the sensors are divided into multiple groups. The packet information and the random key are sent to the sensor using the public and private keys.

c. The resulting sensor grouping information can only be communicated between groups, and external information cannot be passed into the group. The devices in the group reach a synchronized clock through a consensus mechanism.

d. The devices in the group periodically update the keys based on the timestamp and information in the group. The method of updating the key selected in this paper is an improved SM4 algorithm. The new key is spliced with the intra-group information and the random key, and input into the hash function to generate the next encrypted work key.

e. The sensor encrypts the data using the work key and sends it to the blockchain control center. Since the blockchain control center and the sensor are synchronously rotated, the same work key as the sensor can be calculated, and the work key is used to decrypt the data.

The improved SM4 algorithm[20] flow is as follows:

1) The encryption process of the SM4 algorithm divides each plaintext packet and ciphertext packet into 128 bits, and then divides each packet into four parts, namely

plaintext $(P_0, P_1, P_2, P_3) \in (Z_2^{32})^4$. In ciphertext $(Q_0, Q_1, Q_2, Q_3) \in (Z_2^{32})^4$, the round key is $gh_i \in (Z_2^{32})^4, i = 0, 1, 2, \ldots, 31$. The reverse transformation R is

$$R(B_0, B_1, B_2, B_3) = (B_3, B_2, B_1, B_0), B_i \in Z_2^{32}, i = 0,1,2,3 \quad (3\text{-}5)$$

The encryption transformation of the algorithm is:

$$P_{i+4} = F(P_i, P_{i+1}, P_{i+2}, P_{i+4}, gh_i) = P_i \oplus T(P_i, P_{i+1}, P_{i+2}, P_{i+4}, gh_i), i = 0,1,2,..,31 \quad (3\text{-}6)$$

$$(Q_0, Q_1, Q_2, Q_3) = R(P_{32}, P_{33}, P_{34}, P_{35}) = (P_{35}, P_{34}, P_{33}, P_{32}) \quad (3\text{-}7)$$

2) The generation of a work key. Each of the communication parties generates a 128-bit random number, which is represented by U、V, and is encrypted and exchanged by using the public key of the other party; the two parties respectively calculate $J = UV$, and J is called a basic key. First, the left key operation is performed on the basic key J, and the result is denoted as J_R. which is:

$$J_R = R <<< J, R = 0,1,\ldots,127 \quad (3\text{-}8)$$

The 128-bit J_R is divided into 4 groups in the order of binary digit strings, each of which is a group of 32, and (D_0, D_1, D_2, D_3) is named for each group. For (D_0, D_1, D_2, D_3), the left loop and right loop operations are respectively performed according to the algorithm, and the operation result is a new 128-bit number string. which is:

$$J_R E_T = ((T+1) <<< D_0)\&(2(T+1) <<< D_1)\&(D_2 >>> 2(T+1))\&(D_3 >>> (T+1)) \quad (3\text{-}9)$$

The W and the intra-group information, the timestamp is used as the input value of the one-way hash function, and the generated 128-bit output value is used as the working key of the SM4 algorithm:

$$CurrentKey = Hash(J_R E_T, Info, Timestamp) \quad (3\text{-}10)$$

4. Experiment

As shown in Figure 4-1, it is the architecture of the application method of the traceability method proposed in this paper. The experiment is aimed at the sales scene of camellia oil. Using the mode of WeChat e-commerce small program online[21], the system prototype was developed and tested in the field. The system covers the entire supply chain, and realizes full-scale visual traceability and product anti-counterfeiting functions based on IoT devices.

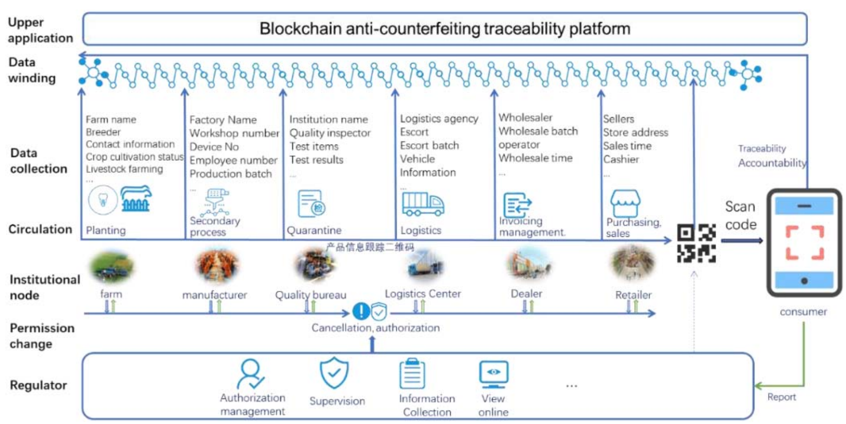


Figure 4-1 Implementation architecture

In the specific implementation process, the traceability system designed in this paper defines specific responsibilities for different users of the user layer according to the overall architecture and technical architecture described above, and sets corresponding implementation strategies to ensure that the system achieves the expected results.

1) Regulatory department: As a constraint on the production, processing, logistics and sales, the regulatory department has a relatively heavy authority in the blockchain system. Enterprises are required to conduct qualification examinations in accordance with the regulations of the regulatory authorities.

2) Agricultural producers: As the source of supply chain data, agricultural producers should be strictly reviewed for their qualifications in order to be eligible to join the system, and to register basic information such as corporate geographic information, related certificates, legal representatives, and node addresses.

3) Product processor: responsible for

product processing and packaging. The regulatory authorities and agricultural producers identify the health and operation of the processors. After passing the qualifications, they are allowed to join the alliance chain, and new contract objects are generated to record basic information such as geographical location, business license, and node address.

4) Logistics: The regulatory authorities and agricultural producers identify the operation status and related qualifications of the logistics enterprises. After passing the qualification, they are allowed to join the alliance chain, and new contract objects are generated to record the basic information such as the corporate legal person, vehicle status and node address.

5) Vendor: The seller is responsible for putting the product on the market and passing the sales of the product to the blockchain platform. The supervisory department and the agricultural producers identify the operation status and related qualifications of the logistics enterprise. After passing the qualification, they are allowed to join the alliance chain, and a new contract object is generated to record the basic information such as the unit name, business license and node address.

6) Consumers: Consumers, as participants outside the blockchain system, access the blockchain system through the cloud blockchain node, and scan all the information in the supply chain traceability process by scanning the QR code on the product packaging bag.

```
pragma solidity ^0.4.22;

contract powerOfLogistics {
    // This is a type for a single proposal.
    struct Proposal {
        bytes32 name;   // short name (up to 32 bytes)
        uint voteCount; // number of accumulated votes
    }


    mapping(address => Voter) public voters;

    // A dynamically-sized array of `Proposal` structs.
    Proposal[] public proposals;

    function Ballot(bytes32[] proposalNames) public {
        chairperson = msg.sender;
        voters[chairperson].weight = 1;

        // For each of the provided proposal names,
        // create a new proposal object and add it
        // to the end of the array.
        for (uint i = 0; i < proposalNames.length; i++) {
            // `Proposal({...})` creates a temporary
            // Proposal object and `proposals.push(...)`
            // appends it to the end of `proposals`.
            proposals.push(Proposal({
                name: proposalNames[i],
                voteCount: 0
            }));
        }
    }
```

Figure 4-2 Sensor public and private key binding smart contract

The user's permissions are stated by the smart contract[22]. One of the important reasons why the blockchain platform can ensure the security of the system is that its execution is based on smart contracts. A smart contract is a set of commitments defined in digital form that promises to control digital assets and includes the rights and obligations agreed upon by contract participants, and is automatically executed by the computer system. It is this automated implementation that eliminates human interference in the system. Figure 4-2 is an example code example of a smart contract that specifies the functions of the logistics party.

Smart contracts not only have the advantage of cost efficiency, but also avoid the interference of malicious behavior on the system. The smart contract is written into the blockchain in a digitized form. The characteristics of the blockchain technology ensure that the entire process of storage, reading and execution is transparent and traceable and cannot be tampered with.

In the supply chain sales side, the experiment used the WeChat applet as a user-oriented front end. An applet is an application that you can use without downloading and installing it. The small program communication uses https access, SSL encrypted communication, and the style code is encapsulated in the WeChat applet, so the security is higher and more stable. This also satisfies the data security considerations of the traceability platform. WeChat's huge user base makes the small program a high business prospect. Figure 4-3 is a partial interface display.

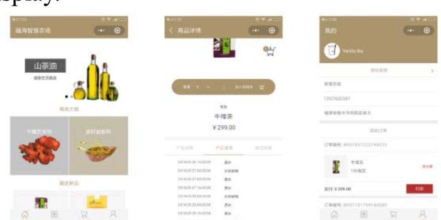


Figure 4-3 WeChat e-commerce applet display

5. Summary and outlook

The work of this paper focuses on how to integrate blockchain, IoT technology and traceability technology. The use of IoT technology has increased the efficiency of planting production and reduced unnecessary waste of resources. The use of blockchain technology improves the security of the system. The nature of the blockchain makes the data in the supply chain more secure and traceable. This paper also proposes an innovative combination of blockchain technology and intelligent technology to combine blockchain data security and practicality.

In the future, the applicability and robustness of the system will require further testing. We will promote the system to more application scenarios, find the system's shortcomings, and improve the system. The blockchain technology chain storage, decentralization, and de-trusting features make it naturally meet the needs of the traceability field. At present, a number of domestic and foreign large enterprises and research institutes have conducted in-depth research on the application of this aspect. It is foreseeable that with the development of technology, there will be a mature traceability scheme based on blockchain technology and even the specific application of blockchain technology in other fields.

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