

Research on Agricultural Product Seed Traceability System Based on Blockchain Technology

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Abstract: To address the concerns of supply chain transparency and agricultural product quality safety, this study investigates a blockchain-based system for tracking agricultural product seeds. The development of the agricultural product traceability system is first reviewed in this study, which also examines the benefits of blockchain technology, including its high transparency, decentralization, and immutability of data. In order to assess how seeds affect the quality of agricultural products based on four important factors—technology, soil, climate, and fertilizer—the study employed the analytical hierarchy process (AHP). The results showed that high-quality seeds are the core factor in improving the quality of agricultural products. In order to guarantee the dependability of seed sources, increase the transparency of supply chain data, and boost farmers' and consumers' confidence in products, this article suggests using blockchain technology to create a seed supply chain traceability system. However, the study also pointed out that blockchain technology faces challenges such as high cost, high latency and difficulty in ensuring the authenticity of data before it is uploaded to the chain. In the future, the convergence of the Internet of Things, big data and artificial intelligence can further increase system efficiency, cut costs and improve the validity of data collecting. As the technology matures and its application is promoted, blockchain is expected to become an important tool for agricultural supply chain management, achieving the goal of "controllable source, traceable process and guaranteed quality".

Keywords: Blockchain technology, agricultural product seed traceability, agricultural product supply chain.

1. Introduction

China has long been ranked first in the world population, accounting for 21% of the world's population, but its crop planting area only accounts for 7% of the world's total. One nation with a big population is China, and ensuring food security for the people is a top priority. In 2013, its annual grain planting area was 1,234,000 square kilometers, and the total grain output was 60.195 billion kilograms [1]. In 2023, China annual grain planting area reached 1,189,391.5 square kilometers, and the total grain output increased to 69.54 billion kilograms [2]. It is evident that China's agricultural sector has grown significantly during the last ten years. However, as Wei Xisan said: In the structural reform of the agricultural supply side, must increase production while also improving quality [3]. Consumers' demand for agricultural products is no longer limited to just filling their stomachs. They

also want to trace the origin of agricultural products so that they can eat with peace of mind and buy with confidence.

The traceability of agricultural products originated from the outbreak of mad cow disease in Europe in the 1970s. In 1997, the European Union issued the Green Book on Food Safety, which took the lead in introducing a traceability system in the production process of beef products. At present, the European Union has established a unified database that records in detail the entire production and sales process of the monitored objects. The traceability of agricultural products in China began in 2006, when the Ministry of Agriculture explicitly suggested creating a traceability system for the safety and quality of agricultural products, which possesses the traits of "segmented and segmented" management. On October 13, 2017, the State Council issued the "Guiding Opinions on Actively Promoting Supply Chain Innovation and Application", which clearly pointed out that the key tasks of China agricultural development are to innovate the agricultural industry organization system, improve the scientific level of agricultural production, and strengthen the traceability of quality and safety. According to the opinion, in order to increase consumer safety, a full-chain traceability system with traceable sources, traceability, and responsibility should be implemented. This system should encompass both upstream and downstream businesses in the supply chain. This paper aims to study the advantages of blockchain technology in seed traceability systems and make reasonable predictions on the future development of this field.

2. Literature Review

Ahuja R, Chugh S and Singh R point out: Seeds are the fundamental and most crucial component in sustainable agriculture. The quality of the seeds has a significant impact on how well the other farming inputs work. Estimates suggest that high-quality seeds directly contribute between 15% and 20% to overall production, depending on the crop, and this contribution can increase to as much as 45% with proper management of other inputs [4]. This shows the necessity of establishing a seed traceability system. Next, Sandeep Chaitanya N, Movva R B and Yeruva S think: Blockchain, with its security, reliability, and traceability, can effectively address the challenges in agriculture and food supply chains, where tracing product origins is complex and time-consuming. Without depending on outside parties or centralized supervision, it offers a safe basis for monitoring seed sources and security information across the supply chain [5]. In order to address the issues of information opacity and unreliability in conventional traceability systems, Li Guofu designs and develops a blockchain-based cucumber seed tracing system. By introducing blockchain technology, the transparency, security and traceability of all links in the cucumber seed supply chain are ensured, and the data of the entire process from breeding to sales can be effectively traced [6]. Liu He summarizes the application progress of blockchain technology in the field of food security, focusing on its advantages in food supply chain traceability, quality monitoring and information security management, and investigates its potential uses in conjunction with artificial intelligence, big data, and the Internet of Things [7].

3. Using AHP to Explain the Importance of Seeds to Crop Growth

AHP, or the Analytic Hierarchy procedure, is a decision-making procedure that breaks down decision-related components into layers like goals, criteria, and plans. Based on this breakdown, it does both qualitative and quantitative analysis. In the early 1970s, Professor Satti, an American operations researcher at the University of Pittsburgh, proposed this approach as a hierarchical weighted decision analysis method. The requirement of seed traceability is suggested in this research, which use AHP to investigate the variables influencing the quality of agricultural goods. It is divided

into four first-level indicators: technology, soil, climate, and fertilizer, and then each first-level indicator is further divided into two second-level indicators, as shown in Figure 1.

3.1. Technology

The improvement of agricultural product quality is inseparable from the progress of science and technology, which is most directly reflected in seed selection and scientific planting. The importance of ensuring grain quality and safety, concentrating on agricultural science and technology innovation, and encouraging the growth of the contemporary seed market were all made abundantly evident in Central Document No. 1 of 2016. A paper titled "Progress in Breeding the Three Lines Using Wild Rice" was published by Professor Yuan Longping at the National Rice Research Conference in Suzhou, Jiangsu, in 1973. This article formally announced the successful breeding of the three lines of Chinese indica hybrid rice, which has since allowed hundreds of millions of people to have enough food; Sichuan farmer Leng Tianhua's farming business depends on the weather, and the planting benefits have always been poor. It was not until 2019 that the agricultural big data platform was introduced, and 13 vegetable greenhouses could be managed with just one mobile phone, greatly saving manpower and material resources.

3.2. Soil

Although soilless cultivation has made great progress with the development of science and technology, it is still far behind traditional soil cultivation. In addition, the core concept of soilless cultivation is to scientifically match trace elements to provide plants with the substances they need for growth. Therefore, when selecting soil to plant agricultural products, it is necessary to pay attention to the differences in trace elements in the soil and the types of crops suitable for planting. For example, sandy soil is relatively dry, loose and breathable, and water and fertilizer are lost quickly. It is suitable for planting drought-tolerant crops, such as corn, soybeans, watermelons, peanuts, etc. The roots of these crops are highly adaptable and can penetrate deep into the soil to absorb nutrients; however, clay soil has small porosity, is airtight, and is prone to waterlogging, so it is necessary to loosen the soil during farming. It is suitable for planting some rice, corn, flour, corn and other legumes, which rely on water to grow to varying degrees [8,9].

3.3. Climate

As the ancients used to say, "You depend on the weather for your food." It is impossible to overlook how environmental elements like temperature and humidity affect the quality of agricultural products. When planting crops, need to develop according to local conditions and understand the local environment and climate in order to grow high-quality agricultural products.

3.4. Fertilizer

Fertilizer is particularly important for the growth of crops. As mentioned above: trace elements provide a continuous source of power for the growth of crops. The role of fertilizer is to make up for the missing trace elements and prevent crops from getting sick, which will cause a reduction in production.

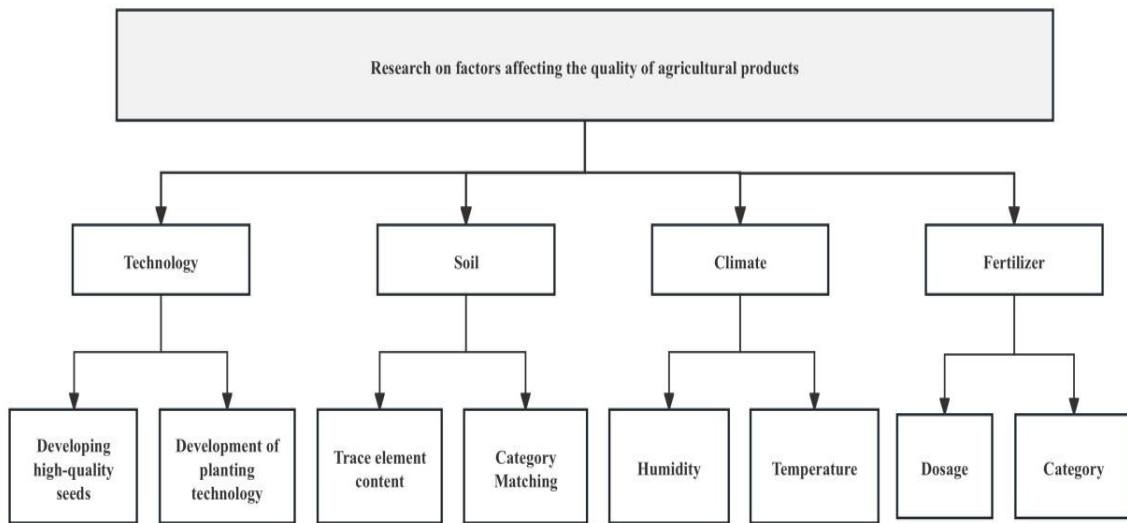


Figure 1: AHP evaluation index distribution diagram.

Note: In AHP, there is an ideal situation: satisfying $a_{ij}=a_{ik} \cdot a_{kj}$ and the rows (columns) of the matrix are in multiples. The matrix that meets this condition is called a consistent matrix. However, the weight setting is subjective, so it is difficult to obtain a strict consistent matrix. Therefore, as long as the difference from the consistent matrix is not large, this process of finding and testing the "difference" is called "consistency test". The formula for calculating the consistency ratio is: $CR=\frac{CI}{RI}$, $CI=\frac{\lambda_{max}-n}{n-1}$.

Table 1 shows RI values. Table 2 shows the weight table of first-level indicators. Table 3 shows the secondary indicator weight table.

Table 1: RI values (When n takes different values).

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table 2: Weight table of first-level indicators.

First-level indicator weight				
Index	Weight	CI	CR	λ_{max}
Technology	0.5967	0.08147	0.0915	4.2444
Soil	0.2292			
Climate	0.1188			
Fertilizer	0.0554			

Table 3: Secondary indicator weight table.

Secondary indicator weight				
Index	Weight	CI	CR	λ_{max}
Developing high-quality seeds	0.0994	0	0	2
Research and development of planting technology	0.4972			
Trace element content	0.1719	0	0	2
Category Matching	0.0573			

Table 3: (continued).

Humidity	0.0989	0	0	2
Temperature	0.0199			
Dosage	0.0277	0	0	2
Category	0.0277			

Table 4: Comprehensive weights of primary and secondary indicators.

First level indicator	Weight	Secondary indicators	Weight	Comprehensive weight
Technology	0.5967	Developing high-quality seeds	0.4972	0.2966
		Research and development of planting technology	0.0994	0.0593
Soil	0.2292	Trace element content	0.1719	0.0393
		Category Matching	0.0573	0.1313
Climate	0.1188	Humidity	0.0989	0.0117
		Temperature	0.0199	0.0023
Fertilizer	0.0554	Dosage	0.0277	0.0015
		Category	0.0277	0.0015

According to Table 4, agricultural technology accounts for 59.67% of the quality of agricultural products, of which high-quality seeds account for 49.72% of the impact on crop quality. This vividly illustrates that ensuring seed safety can greatly improve the quality of crops. In order to successfully guarantee the quality and safety of seeds, this article aims to present blockchain technology for tracking the origin of seeds.

4. Blockchain Traceability Technology

4.1. Definitions

In 2008, Satoshi Nakamoto introduced the first blockchain when he put out the idea for the Bitcoin cryptocurrency. Without a central bank or other third-party middleman, digital currency might be exchanged within an untrusted network of anonymous nodes thanks to this well-known and acknowledged use of blockchain technology in the financial sector. Nonetheless, a wide range of other industries, including healthcare, smart cities, energy markets, smart contracts, and government, are now utilizing blockchain technology. The following characteristics are key to this technology's success: immutability, transparency, and dependability.

4.2. Based on its Application as a Shared Database

4.2.1. Decentralization

The current traceability system's information flow is highly dependent on the center. All information within the system needs to be transmitted to the center for safekeeping and then sent out by the center when used. This model is not only costly, but also extremely vulnerable to attacks and information loss.

In the traditional seed supply chain, farmers become consumers, and traceability information is provided by seed suppliers. Once the supplier information is lost, farmers cannot synchronize the

seed information to the agricultural product supply chain, that is, the chain is incomplete upstream. The purchasing power of downstream retailers and consumers in the crop supply chain for such crops with unclear sources will deteriorate, so farmers' profits will decrease and the purchase volume from seed suppliers will also decrease. If this cycle continues, the loss of utility is unpredictable. Blockchain is decentralized, and all nodes can be regarded as centers. In the seed supply chain, suppliers lose their central position. Even if their information is lost, the data is still in the hands of distributors and farmers. In this way, the agricultural product supply chain information will not be lost.

4.2.2. Traceability

Traceability is the ability to track the provenance of any data on the blockchain using the chain structure and to store all historical data after the genesis block using the block data structure. The traceability function of the blockchain allows consumers to accurately obtain information such as the production location and production time of the product, enhancing the credibility of the product. As consumers in the seed supply chain, farmers must make full use of the traceability of blockchain technology to ensure the quality and sales of their crops in the future and firmly control the quality at the source. This will ensure that future consumers of agricultural products can trace the source of their crops, not just the origin, but also a clear understanding of the source of the seeds, such as whether they are the product of genetically modified seeds, whether the seeds of the agricultural products are imported from foreign countries or cultivated domestically after introduction, etc.

Using blockchain technology to track the origin of items is really quite prevalent. For instance, Walmart and IBM have been collaborating since 2016 to implement blockchain-based traceability across the food supply chain. Walmart started its worldwide blockchain strategy by making sure the Chinese market's pork supply chain was secure. In order to promptly record the farm source details, batch number, factory and processing data, expiration date, storage temperature, transportation details, and other product information of pork, as well as information on each process, on a secure blockchain database, this project makes use of IBM's blockchain technology based on Hyperledger, an open source program under the Linux Foundation. Through the implementation of this project, Walmart can check the origin of the pork it distributes and the process of each intermediate transaction at any time to ensure that the goods are verified. Users can learn detailed information about the product by scanning the QR code on the product packaging, so that users will be willing to pay for it.

4.2.3. Unalterable

Unalterable means that the recorded information has not been changed. All nodes record the information once it has been put to the blockchain by consensus, and cryptography is employed to make sure it is connected. Tampering is very expensive and complicated. The reality of multiple breeding and varied business structures occurs due to the vast number of seed businesses currently in operation and the rapid development in crop varieties. The phenomena of "similar varieties", "copycat brands," and "channelling" are also common. There are many cases of selling inferior products as good ones.

Some suppliers use the name of a high-quality seed company, then purchase cheap and low-quality seeds and supply them to make a profit from the price difference. However, blockchain technology usually uses the SHA-256 hash algorithm to encrypt blocks. Since this method is irreversible, the resultant hash content cannot be used to deduce any information about the original text. The hash output will be significantly altered by any change in the input data, even if it is only a single digit. The hash algorithm can be used to check if the data has been altered based on the one-to-one connection

between the output hash and the original text input. This will ensure that all of the seed supplier's information is stored in the chain and cannot be altered, significantly enhancing the information's dependability.

4.2.4. Open and Transparent

Blockchain technology records every transaction through asymmetric encryption and timestamps, allowing all parties involved in the transaction to see it. This is a completely open and transparent transaction method. When a dispute occurs, anyone can access the relevant information at the first time. Anything built and stored in a blockchain can be publicly accessed, and the data stored in it can be tracked, creating a higher standard of accountability for those who use the system.

5. Conclusion

This paper uses the AHP method to emphasize the importance of seeds to the quality of agricultural products, and proposes the introduction of blockchain technology to track the seed supply chain. Traceability not only makes it easier for consumers to track the source of products, but also helps to trace responsibilities and protect the rights and interests of farmers. However, blockchain technology still faces challenges such as high cost, high latency and difficulty in promotion, and the authenticity of data before being uploaded to the chain is difficult to guarantee. Big data, artificial intelligence, and the Internet of Things can all be combined to optimize the traceability system in the future, increasing its viability and efficiency. It is anticipated that blockchain will be extensively utilized in the agricultural supply chain to accomplish the objective of "controllable source, traceable process, and guaranteed quality" as the technology advances and costs come down.

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