ISSN 2616-5902 Vol. 7, Issue 12: 132-138, DOI: 10.25236/AJBM.2025.071217

Research on Value Creation of Blockchain-Enabled Quality Traceability for Agricultural Products: A Case Study Based on the Litchi Industry in Zhenlong Town, Huizhou

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Abstract: *Taking the litchi industry in Zhenlong Town, Huizhou as a case study, this paper systematically explores the value creation mechanism of blockchain-enabled quality traceability for agricultural products. Addressing the pain points in traditional traceability—such as difficulties in standardizing production-end data, mixed packaging in the circulation stage, and counterfeiting in the consumption sector—and combining the adaptability of blockchain's characteristics of decentralization and immutability, this paper elaborates on the implementation path of blockchain across the entire process of production, processing, and sales by leveraging the compatibility of blockchain's core features (decentralization and immutability). It quantifies the economic and social values generated by this approach and puts forward targeted optimization recommendations, including policy support and technology integration. This research aims to provide a practical paradigm for the digital transformation of agriculture.*

Keywords: *blockchain; agricultural product traceability; value creation; agricultural supply chain*

1. Introduction

While the modernization of agriculture is advancing at an accelerated pace, food safety incidents occur frequently. Meanwhile, residents' consumption structure continues to upgrade, leading to a strong public demand for high-quality and safe agricultural products. However, the core contradiction in agricultural product quality and safety—information asymmetry between production and sales—still gives rise to market failure and trust crises. The opacity of information and difficulties in traceability within traditional supply chains further undermine consumer confidence and safety guarantees. Traditional traceability systems suffer from shortcomings such as information barriers, weak anti-counterfeiting measures, and heavy manual intervention.

Blockchain technology, with its characteristics of decentralization, immutability, and traceability, can effectively address the above pain points. While improving quality safety and consumer trust, it creates multi-dimensional value for agricultural products by enhancing information transparency, optimizing supply chain management, innovating financial services, and promoting industrial digitalization—thereby facilitating the transformation and upgrading of the entire agricultural chain[1]. Currently, the construction of "Digital China" explicitly promotes the integration of technologies such as blockchain with agriculture; rural revitalization also requires technological empowerment. These two factors jointly provide support for the application of blockchain in agriculture, which also aligns with the urgent needs of food safety and consumption upgrading.

Blockchain has been incorporated into "new infrastructure" initiatives. In 2020, the National Development and Reform Commission (NDRC) clearly defined its key role in the digital economy. The 14th Five-Year Plan for Digital Economy Development emphasizes an application-oriented approach. Research focuses on the optimization of traceability technologies, expansion of application scenarios, and innovation of business models, aiming to build a credible system covering the entire lifecycle of agricultural products.

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2. Theoretical Analysis

2.1 Definition of Blockchain

Blockchain is a decentralized, distributed, and tamper-resistant database technology that leverages cryptography, consensus mechanisms, and peer-to-peer (P2P) networks to ensure secure data storage and transmission. Its core philosophy lies in establishing a collaborative framework that operates without reliance on trusted third parties, thereby addressing trust issues inherent in centralized systems through technical means. Key characteristics include decentralization, immutability, transparency and verifiability, and consensus mechanisms. The system is structured on a "block-and-chain" architecture, where each block consists of a block header and a block body, interconnected through cryptographic hashing. Based on access permissions, blockchains can be categorized into three types: public chains, private chains, and consortium chains. Currently, the application of this technology has expanded beyond digital currencies to various fields such as agricultural product traceability, copyright management, and governmental record-keeping. By utilizing self-executing smart contracts, blockchain enhances transaction efficiency and data credibility, contributing to more secure and transparent developmental pathways across industries.[2]

2.2 Core Characteristics of Blockchain

2.2.1 Decentralization

Blockchain abandons the centralized management model and adopts a distributed architecture where nodes collectively maintain data. The system operates without a single governing entity, with all participating nodes enjoying equal status and collaborating to accomplish data verification, storage, and dissemination. This characteristic helps avoid data loss or system failure caused by single points of failure and reduces the risk of malicious data tampering. In agricultural product traceability, it ensures that data from each stage is recorded by multiple entities, thereby preventing data inaccuracies resulting from unilateral operations.

2.2.2 Immutability

This represents a core technical characteristic of blockchain: once data is confirmed by node consensus and written into the system, it becomes immutable and non-erasable. As each block contains the hash of the previous block, tampering with any single block would cause a cascading change in the hash values of all subsequent blocks, leading the network to recognize the chain as invalid. Combined with the protection of cryptographic algorithms, this mechanism further enhances data security, establishing a reliable and trustworthy information foundation for agricultural product traceability.

2.2.3 Traceability

Leveraging its chain structure, blockchain retains complete records of all transactions with tightly interlinked blocks, forming an end-to-end data trail that can be traced back to the origin. In agricultural product traceability, this enables comprehensive tracking of information across the entire process—from cultivation and processing to transportation and sales—thereby empowering consumers to fully understand product quality and helping reduce food safety incidents.

2.2.4 Transparency

Blockchain data is characterized by its openness and accessibility, allowing all nodes to view and verify on-chain information. This feature enhances consumer trust in agricultural product quality, facilitates real-time data sharing and supervision among supply chain entities, improves information transmission efficiency, mitigates market information asymmetry, and supports the healthy development of agricultural markets.

2.3 The Development Status of Blockchain

As an innovative technology integrating distributed storage, peer-to-peer transmission, consensus mechanisms, and encryption algorithms [3], blockchain technology has expanded from its early application in the financial sector to multiple dimensions of social economy, demonstrating enormous application potential.

In terms of technological evolution, blockchain is advancing from the cryptocurrency-focused Blockchain 1.0 era to the Blockchain 2.0 era (featuring smart contracts) and further to

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the Blockchain 3.0 era (focused on industry-wide applications). Technological platforms are becoming increasingly mature, performance is continuously improved, and application costs are gradually decreasing.

In specific industrial applications, blockchain has moved beyond mere conceptual verification and achieved large-scale implementation in fields such as supply chain management, product traceability, government services, and agriculture—with particularly robust development momentum in the agricultural sector [4]. Data shows that the scale of China's agricultural blockchain market has grown rapidly from approximately RMB 1.14 billion in 2020 to RMB 2.364 billion in 2024, doubling in size over four years. Figure 1. Growth of China's Blockchain Market Size from 2020 to 2024 intuitively visualizes this robust growth trajectory through a clear bar chart, with the horizontal axis marking the year and the vertical axis indicating the market size in RMB billions, making the market expansion trend easy to grasp at a glance. This rapid growth trend clearly indicates that blockchain technology is being accelerated in its application across the entire chain of agricultural products (from production to consumption), and its value has shifted from pure technological exploration to bringing tangible efficiency improvements and value creation to the industry.

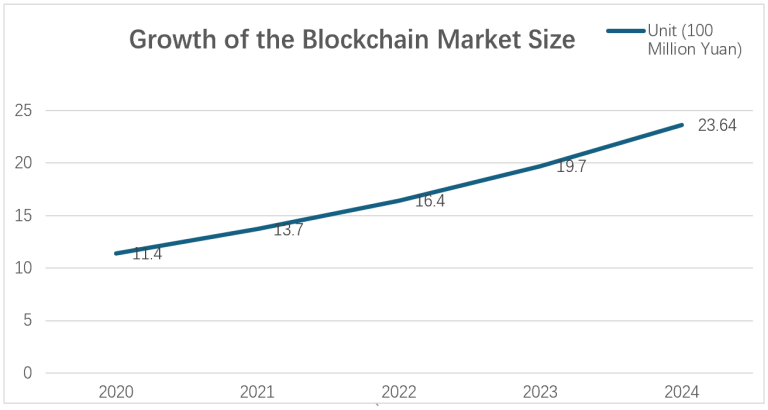

Figure 1. Growth of China's Blockchain Market Size from 2020 to 2024

3. Case Study of Zhenlong Litchi in Huizhou: An Analysis of the Value Creation Process of Blockchain-Enabled Traceability

3.1 Traceability Pain Points in Huizhou Zhenlong Litchi Industry and the Compatibility of Blockchain

Traditional agricultural product traceability faces pain points such as information silos and vulnerable data tampering. However, the characteristics of blockchain technology—decentralization and immutability—are highly compatible with the solutions to these pain points, enabling the effective construction of a credible data chain.

The traceability pain points of the litchi industry in Zhenlong Town, Huizhou are as follows: First, the scattered distribution of fruit farmers at the production end makes it difficult to collect data in a standardized manner, and the authenticity of data is hard to guarantee, resulting in traceability information becoming a mere formality and lacking credibility. Second, in the circulation link, purchasers tend to mix litchis from different producing areas in packaging. Third, the counterfeiting of "Zhenlong litchi" at the consumption end severely undermines the sales of authentic products.

Traditional traceability methods are unable to solve these problems, while blockchain can play a key role: its immutability ensures data credibility, and when combined with management measures, it can achieve transparency in the circulation process—effectively addressing the aforementioned pain points.

3.2 Implementation Path of Blockchain-Enabled Traceability in Huizhou Zhenlong Litchi Industry

The construction of the blockchain traceability system for the litchi industry in Zhenlong Town, Huizhou follows the core principle of "full-chain closed-loop management from production end to consumption end," forming a set of interlocking implementation paths. This path is a systematic project that deeply integrates production standards, IoT data collection, blockchain information certification, and

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marketing, and its operation logic fully aligns with the framework of Figure 2. Blockchain Traceability Flowchart for the Full Lifecycle of Agricultural Products—which maps out the full-process traceability chain from seed selection to consumer verification. It aims to convert the full-lifecycle information of litchis—from cultivation, harvesting, processing to sales—into immutable and verifiable digital assets, laying a solid foundation for eventual brand value enhancement and a trust-based economy.

In the production link, fruit farmers input data (including orchard location, litchi variety, cultivation records, fertilization records, pesticide application records, and growth environment information) via mobile terminals. IoT devices such as sensors and cameras collect data in real time and upload it to the blockchain; the immutability of blockchain ensures data credibility. The integration of Zhenlong's smart agriculture with traditional cultivation practices provides support for data collection.

In the processing link, processing plants record and upload information (including processing techniques, packaging materials, quality inspection reports, and spatio-temporal data of processing) to the blockchain through web applications, realizing process transparency. This can refer to the processing link application model of the National Chain Blockchain Agricultural Product Traceability System.

In the transportation link, logistics companies record and upload information (including transportation routes, timelines, and vehicle temperature control data) to the blockchain via web applications[5]. Consumers can check the transportation status through traceability codes, reducing information asymmetry.

In the sales link, distributors record and upload information (including sales spatio-temporal data, prices, and channels) to the blockchain. Consumers scan the code to obtain full-process information, which enhances trust and drives brand premium and sales growth.

Through blockchain, the Zhenlong litchi industry has built an efficient and credible information flow system, empowering industrial upgrading.

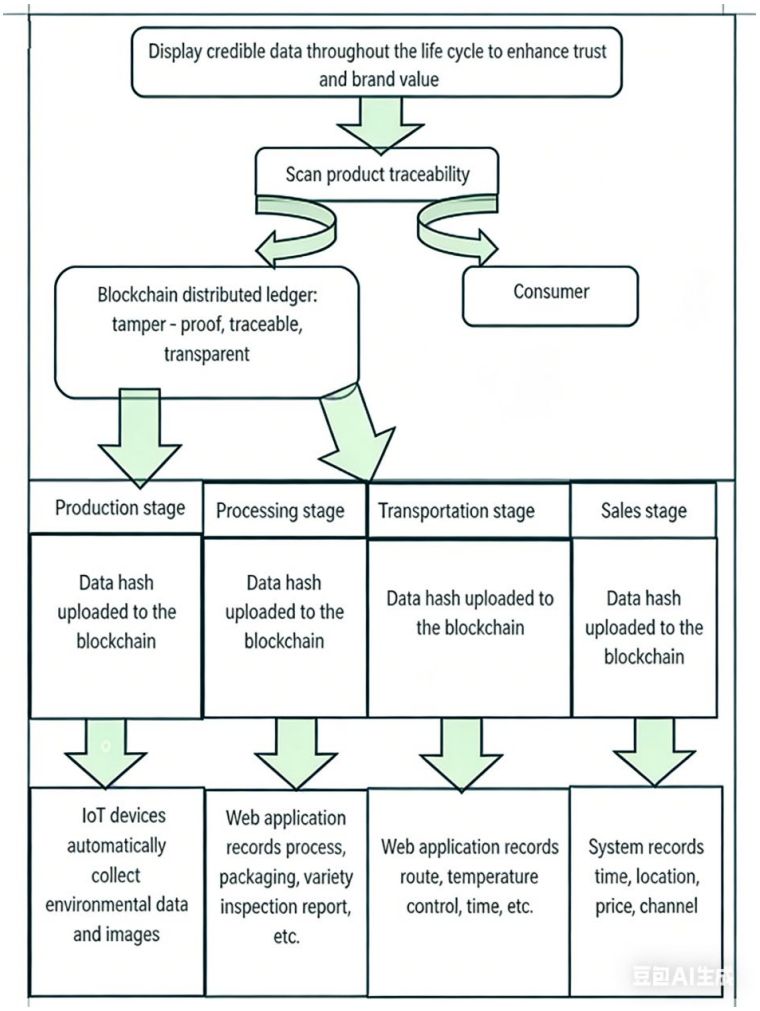

Figure 2. Blockchain Traceability Flowchart for the Full Lifecycle of Agricultural Products

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3.3 Value Creation Analysis of Blockchain-Enabled Traceability Application in Huizhou Zhenlong Litchi Industry

The value creation of blockchain empowering the Zhenlong litchi industry is mainly reflected in two dimensions: economic and social.

3.3.1 Economic Value

The application of blockchain traceability technology has directly enhanced the economic benefits of the Zhenlong litchi industry through two core pathways: "cost reduction and efficiency improvement" and "premium-based revenue growth".[6]

In terms of cost control, blockchain-based precision agricultural management has reduced pesticide usage by 30%, saving approximately RMB 600 per mu (1 mu ≈ 0.067 hectares) in annual plant protection costs. Meanwhile, the optimized cold chain logistics management supported by the traceability system has significantly reduced the fresh fruit loss rate from 15% to 5%, improved transportation efficiency by 70%, and lowered the overall supply chain transaction costs by approximately 20%.

In terms of revenue creation, the brand effect supported by credible data has enabled high-end litchi products to achieve a 10%-15% market premium and driven an 8% increase in the overall average price. Ultimately, this is reflected in a 12% growth in the per capita annual income of litchi farmers across the town. Additionally, the credible quality endorsement has greatly expanded the market boundary: it is estimated that by 2025, the export volume will reach 3,000 tons, the proportion of e-commerce sales channels will exceed 42%, and the pre-sale scale will reach 15,600 tons through production-sales matchmaking conferences. This has formed a positive economic cycle of "quality assurance → brand trust → market premium → farmer income growth → industrial upgrading".

3.3.2 Social Value

The blockchain traceability system has generated extensive positive externalities for society, with its core lying in the construction of a low-cost trust transmission mechanism.[7]

First, it has significantly improved food safety governance and consumer well-being. By establishing a three-level quality inspection network covering 128 testing indicators and synchronizing the results to the blockchain, the over-standard rate of pesticide residues has dropped from 3.2% to 0.8%. This verifiable safety guarantee has increased consumer satisfaction from 72% to 91% and improved the repurchase rate by 25%, transforming the abstract concept of "safe consumption" into a concrete consumer experience and reshaping the food safety trust system.

Second, this technology has strongly promoted industrial collaborative development and rural structure optimization. It has driven 35 cooperatives to form a digital industrial cluster, attracting the participation of more than 300 upstream and downstream enterprises, and has jointly created over 5,000 job opportunities. The Zhenlong litchi industry has also been successfully incorporated into the "Vegetable Basket" Project of the Guangdong-Hong Kong-Macao Greater Bay Area, with a brand value evaluated at RMB 1.09 billion.

More profoundly, agricultural digitalization empowered by blockchain has attracted young people to return to their hometowns for entrepreneurship, providing a new path to alleviate rural aging and hollowing-out problems. In this process, blockchain plays the role of a "trust engine": it protects honest entities and curbs counterfeiting through technical means, and conveys a clear signal to society that "integrity is value," thereby activating the endogenous driving force for rural development.

4. Policy Recommendations for Blockchain Empowering Agricultural Product Quality Traceability

4.1 Strengthen Top-Level Design and Formulate a Unified Standard System

It is suggested that the agricultural and rural departments take the lead in formulating national and industrial-level general standards for agricultural product blockchain traceability, and clarify core specifications such as data collection, on-chain format, and privacy protection. This initiative aims to avoid the formation of new "data silos" at the source, lay a foundation for building a nationally recognized credible traceability network, and reduce the application threshold and technical costs of the entire industry.

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4.2 Innovate Support Methods and Stimulate the Vitality of Market Entities

Governments at all levels should establish special support funds and provide equipment subsidies and loan interest discounts to new agricultural business entities that take the lead in applying blockchain traceability. Meanwhile, financial institutions should be encouraged to develop financial products such as "brand credit loans" based on traceability data, converting technological investment into financing convenience. This will effectively stimulate the endogenous motivation of enterprises, especially small and medium-sized farmers, to participate in the construction of the traceability system [8].

4.3 Promote Data Integration and Expand the Extensibility of Traceability Value

Policies should guide the value of traceability data to go beyond the single function of "anti-counterfeiting inquiry" [9]. Enterprises should be supported to directly apply for product certifications such as green and organic certifications using credible on-chain data, and explore the application of aggregated industry data in fields such as production credit insurance and regional brand value evaluation. This will enable traceability data itself to become a core asset driving industrial decision-making and value creation.

4.4 Strengthen Market Cultivation and Create an Environment of "High Quality for High Price"

Market supervision and publicity departments should work in coordination to educate the market through authoritative channels and shape the consumption concept of "paying for credible quality". Measures such as giving priority to selecting traceable agricultural products in government procurement can be adopted to guide and cultivate a new-type consumer market, form a reverse mechanism of "high quality for high price" from the demand side, and build a positive cycle of quality benefits and farmers' income growth.

5. Conclusion

This This study indicates that blockchain technology, with its characteristics of immutability and traceability, has injected strong "trust" value into agricultural product quality traceability and achieved significant economic and social value creation in the litchi industry of Zhenlong, Huizhou.

At the economic level, blockchain traceability not only realizes "cost reduction" by optimizing production and logistics processes but also achieves "market premium" through quality endorsement supported by credible data. This directly increases the income of litchi farmers and forms a positive cycle of "high quality → premium price → income growth".

At the social level, this technology has built a transparent food safety governance system[10], improved consumer trust and satisfaction, and at the same time promoted industrial collaboration, attracted the return of talents, and activated the endogenous driving force for rural development.

The case confirms that the core value of blockchain empowering traceability lies in converting technological advantages into credible data assets, and ultimately driving the industry to achieve an overall upgrade from "scale expansion" to "quality and efficiency". This provides a replicable practical path for the branding and digitalization of China’s characteristic agricultural products.

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