

# Exoration on the Method and System of Enhancing the Reliability of Quality Traceability in the Sports Industry Chain through Blockchain

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## ABSTRACT

With the rapid development of the sports industry, quality traceability and credibility issues have become important issues in the sports industry chain. Traditional quality traceability and credibility assurance methods have shortcomings in efficiency and accuracy, and emerging technologies need to be adopted to solve them. Blockchain technology is considered an important means to address quality traceability and credibility issues in the sports industry chain due to its decentralized, transparent, and tamper resistant characteristics. This article proposed a quality traceability and credibility assurance system based on blockchain technology to address the issues of quality traceability and credibility in the sports industry chain. The system adopted blockchain technology to achieve quality traceability and information credibility assurance in the production, circulation, and consumption processes of sports products. The system adopted distributed ledger technology to record the production, circulation, and consumption records of products, and achieved automated quality inspection and transaction verification through smart contracts. The experiment in this article showed that using this system can improve efficiency and reliability by 80% -95%. The research on methods and systems for enhancing the credibility of quality traceability in the sports industry chain through blockchain can effectively improve the quality traceability ability of the sports industry chain, thereby safeguarding consumer rights and market stability.

**Keywords:** Blockchain technology, Sports Industry Chain, Quality Traceability, Credibility Guarantee

## 1. Introduction

More and more enterprises have entered the sports industry, forming a huge industrial chain.

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However, due to information asymmetry and lack of transparency, there are many problems in the sports industry chain, such as counterfeit and inferior products, fraudulent behavior, etc. These issues not only harm the interests of consumers, but also affect the healthy development of the entire industry. With the continuous growth of consumer demand for sports products and services, the sports industry chain has gradually become an emerging industry with broad development prospects. Meanwhile, due to the involvement of multiple links and participants in the sports industry chain, how to ensure its quality and credibility has also become an important issue. In recent years, blockchain technology has been widely applied in the quality tracing, source tracing, anti-counterfeiting tracing, and other aspects of the sports industry chain, providing new solutions to enhance the credibility and quality of the sports industry chain.

How to improve the quality and credibility of sports products through emerging technologies, as well as how to establish a comprehensive quality traceability and credibility guarantee mechanism, have become important issues in the sports industry chain. Chen Wenjie believed that industrial integration is an innovative manifestation of regional economic theory [1]. Marlon Meier analyzed the current adoption of enhanced manufacturing technology in the innovation process of the sports industry [2]. McCullough Brian P stated that the relationship between sports and the natural environment is bidirectional, meaning that sports affect and are also influenced by the natural environment [3]. Kolyperas Dimitriosy studied the role of fans in the co creation of sports value. Through five cases, the three roles of assimilation, adaptation, and certification in value co creation were clarified [4]. The above scholars believed that with the improvement of people's living standards and attention to health, the sports industry has become an independent, diversified, and rapidly growing industry.

Blockchain technology can bring many changes and innovations to the sports industry. Cao Yan developed a blockchain IoT quality traceability system using the alliance chain model and the Hyperledger blockchain platform. Experimental testing proved that production enterprises, logistics, and consumers can participate in product information authentication through this system [5]. Fran Casino believed that traceability has become a key element in supply chain management. He developed a distributed functional model that provides decentralized and automated food supply chain traceability based on blockchain technology and intelligent contracts [6]. Haleem Abid studied the basis for building a framework for implementing traceability systems in the food supply chain, and helped decision-makers and practitioners identify and evaluate the driving factors related to implementing traceability systems in the food supply chain. He also provided useful insights and support for practitioners and managers in decision-making on issues related to traceability implementation [7]. Ziyao Zhang proposed a quality traceability system framework for prefabricated components based on blockchain technology [8]. The above scholars believed that blockchain technology provides an effective solution for changing the centralized storage mode and related drawbacks of traditional traceability systems.

Blockchain technology has great potential in addressing quality traceability and credibility issues in the sports industry chain. Blockchain technology stores data in a decentralized way, and does not rely on centralized institutions to manage and control the flow of information, thus avoiding the problem of information tampering and forgery, and improving the credibility and transparency of data. The use of hash algorithms and encryption techniques ensures the immutability of data, meaning that once data is recorded on the blockchain, it cannot be modified or deleted, thus ensuring the authenticity and reliability of the data. Automated quality detection and transaction verification can be achieved through smart contracts, which avoids the human omissions and fraud issues that exist in traditional manual detection and verification processes. It can achieve data sharing and information exchange, and promote collaboration and information sharing among all parties, thereby improving the efficiency and transparency of the entire sports industry chain.

## 2. Blockchain Technology and Its Applications

### 2.1. Blockchain Technology and Sports Industry Chain

Blockchain has many advantages, such as decentralization, persistence, anonymity and auditability. Blockchain has a wide range of applications, from cryptocurrencies, financial services, risk management, the Internet of Things to public and social services [9]. Blockchain is a technology that makes the concept of shared registry in distributed systems a reality in many application fields, including from cryptocurrencies to any potential industrial system that requires decentralized, robust, trustworthy, and automated decision-making in a multi stakeholder situation [10-11].

The sports industry chain refers to the whole process from the design, production, circulation, sales, consumption and abandonment of sports products, including sports goods production enterprises, sports event organizers, stadiums, sports club, sports goods retailers and other links. The characteristics of the sports industry chain are clear division of labor, long industrial chain, numerous links, wide coverage, high risks, and the problems of difficult quality traceability and low credibility.

By adopting blockchain technology to solve the quality traceability and credibility issues in the sports industry chain, the full process quality traceability and information credibility guarantee of sports products can be achieved, and the quality and credibility of sports products can be improved, thereby protecting the rights and interests of consumers and promoting the healthy development of the sports industry.

### 2.2. Application of Decentralized Characteristics of Blockchain Technology in the Sports Industry Chain

A blockchain consists of a sequence table containing nodes and links, where nodes store information and connect through links called chains [12]. The new generation of blockchain applications is still constantly evolving, and the technological features of blockchain are also constantly improving. The undisputed and widely known feature that data in blockchain cannot be edited or deleted remains the cornerstone of blockchain security [13]. Blockchain is essentially a decentralized distributed database technology, which is a network composed of multiple nodes. In the sports industry chain, the management and sharing of data can be achieved through the following methods. Public chain: Public chain refers to a blockchain network that everyone can participate in, and data can be shared and viewed by everyone. In the sports industry chain, the public chain can be used to record public data such as the results of sports matches, bonus distribution, and player information, ensuring transparency and fairness of the data. Alliance chain: Alliance chain refers to a blockchain network jointly maintained by several organizations or institutions, where data can only be shared and viewed by authorized organizations or institutions. In the sports industry chain, alliance chains can be used to record information related to the organization, sponsors, teams, athletes, and other aspects of sports events, ensuring the privacy and security of data. Private chain: Private chain refers to a blockchain network maintained by a single organization or institution, where data can only be shared and viewed by that organization or institution. In the sports industry chain, the private chain can be used to record the internal data of the organization, such as the management information and financial information of sports club. The above three methods can be selected and combined according to the actual situation to achieve data management and sharing.

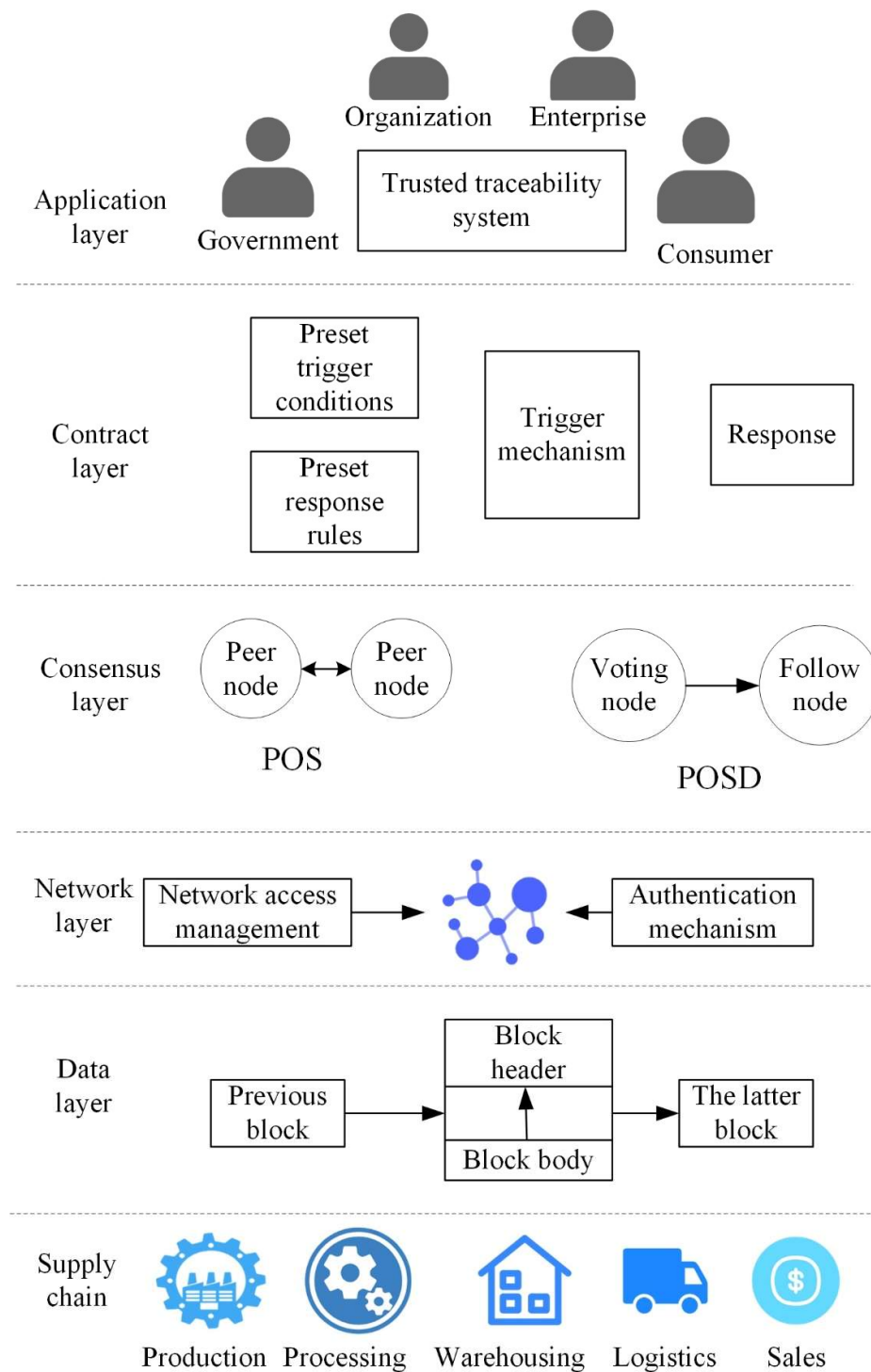
### 2.3. Smart Contracts

In sports competitions, smart contracts can be used to automatically execute these programs. Bonus allocation: Smart contracts can set bonus allocation rules before the competition. It automatically calculates the prize money for each winner based on the competition results and transfers the prize money to the recipient's account, thereby ensuring the fairness and transparency of the prize money.

Player transfer: Smart contracts can automatically execute player transfer transactions when transfer conditions are met, such as automatically completing player transfer transactions when transfer fees and salary conditions are met, and recording relevant information on the blockchain to ensure fairness and transparency of transfers. Ticket sales: Smart contracts can automatically execute ticket sales procedures on ticket sales channels. It can automatically record relevant information such as sales quantity, price, and ticket buyer information, and can achieve anti-counterfeiting function of competition tickets, thereby ensuring the authenticity and credibility of competition tickets. Team management: Smart contracts can automatically execute programs in team management, such as player salary management, team financial management, team member management, etc., thereby improving management efficiency and reducing human errors. These are some programs that smart contracts can implement, and the design of smart contracts needs to consider specific application scenarios and requirements to ensure the reliability and security of the contract.

#### *2.4. Multi Party Consensus Mechanism*

The multi-party consensus mechanism can achieve consistency of data on the blockchain, thereby ensuring the authenticity and credibility of the data. It can ensure data consistency in various links such as manufacturers, quality inspection agencies, intermediaries, retailers, etc.: in the sports industry chain, data recording and verification involving multiple links can be ensured through a multi-party consensus mechanism to avoid data tampering and forgery. It can improve the quality traceability credibility of sports products: adopting a multi-party consensus mechanism can ensure the authenticity and credibility of data on the blockchain, and enable consumers to trust the quality traceability information of sports products more, which can improve consumer satisfaction and loyalty. It can prevent malicious attacks and single point of failure: the adoption of a multi-party consensus mechanism can enhance the security and stability of the blockchain system, and avoid attacks by malicious nodes and the impact of single point of failure, thus ensuring the security and stability of the sports industry chain data. It can achieve automated quality control and certification: using smart contract technology combined with multi-party consensus mechanisms can achieve automated quality control and certification, and can improve the production efficiency and quality level of sports products. It can establish a traceability system: through blockchain technology, a sports industry chain traceability system can be established, which can record data from all aspects of sports product production, circulation, sales, etc. For counterfeit and inferior products, they can be traced back to the source, which can better protect consumer rights and the healthy development of the entire sports industry. This article constructed a trustworthy traceability system framework suitable for sports industry traceability based on blockchain, as shown in Figure 1.



**Fig. 1.** Trusted Traceability System Technical Framework

(POS, Proof of Stake) (POSD, Proof of Stake and Delegation)

The framework of blockchain technology includes network layer, data layer, consensus layer, smart contract layer, and application layer. The core of blockchain technology includes parts such as ledger management, sending and receiving management, password management, consensus management, smart contracts, and system management. Ledger management is responsible for maintaining the data structure and storage methods of blockchain. Transceiver management is the data transmission part of blockchain technology, which is responsible for data transmission and verification between nodes. Password management is the security guarantee part of blockchain technology, responsible

for identity authentication and data encryption between nodes. Consensus management is the key to blockchain technology, which solves the problem of data consistency between nodes. The writing, deployment, and execution of smart contracts is one of the important applications of blockchain technology. System management is the maintenance part of blockchain technology, responsible for the deployment, operation, and monitoring of nodes. These core components are indispensable parts of blockchain technology, each playing an important role.

### *2.5. Design of Sports Industry Quality Traceability System*

The sports industry chain quality traceability and credibility enhancement system based on blockchain technology mainly includes the following aspects. Data collection and storage module: This module is responsible for collecting and storing data on the production, circulation, and sales of sports products, including product production batches, manufacturers, logistics information, sales records, etc. Data processing and encryption module: This module is responsible for processing and encrypting the collected data to ensure the security and privacy of the data. Using blockchain technology to encrypt and hash data can ensure that it is not tampered with or stolen, while protecting user privacy. Blockchain storage and verification module: This module is responsible for storing encrypted data on the blockchain and providing blockchain verification services. By utilizing the immutability and decentralization characteristics of blockchain technology, the authenticity and credibility of data are ensured. Users can check the production, circulation, and sales information of sports products through verification services to ensure the quality and credibility of the products. User interface and interaction module: This module is responsible for the interaction and data display between users and the system. Users can query and manage information about sports products through web pages, apps, and other means, as well as submit feedback and suggestions to improve the operational efficiency and user experience of the sports industry chain. Through the design and implementation of these modules, the sports industry chain quality traceability and credibility enhancement system based on blockchain technology can achieve full lifecycle management and traceability of sports products, ensuring the authenticity and credibility of the products. A screenshot of the sports industry quality traceability web system is shown in Figure 2.

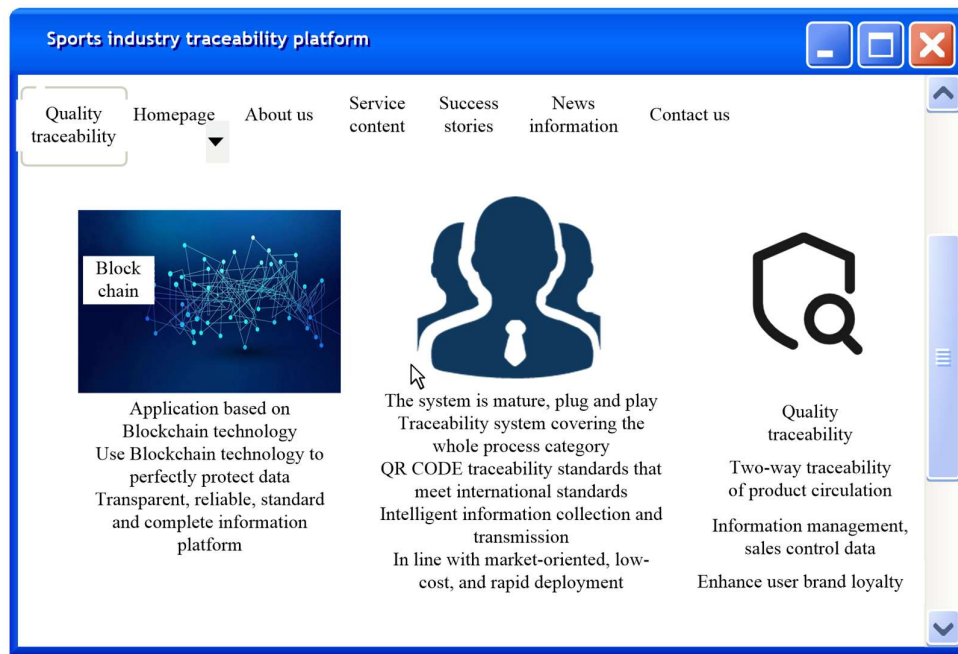


Fig. 2. Screenshot of the Sports Industry Quality Traceability Web System

### 3. Eigamal Encryption Algorithm

#### 3.1. Eigamal Encryption System

In the research on methods and systems for enhancing the credibility of quality traceability in the sports industry chain through blockchain, the ElGamal encryption system can be used to protect data security and privacy in the sports industry chain. ElGamal encryption system is a public key encryption algorithm that can achieve data encryption and decryption, and ensure the confidentiality and integrity of data, thereby avoiding data tampering or leakage. Yu Zhang proposed an EC-ElGamal (Elliptic Curve ElGamal) encryption algorithm with a double trap gate decryption mechanism. A smart grid data aggregation scheme that supports privacy protection and functional queries was proposed using this algorithm and the elliptic curve Schnorr signature scheme. This solution allowed the control center and users to initiate various functional queries on encrypted data [14]. Wanyu Lin proposed a new mechanism to support parallel privacy protection similarity search in distributed key value storage in the cloud, with a focus on efficient addition and deletion operations, both of which are executed with sub linear time complexity. If search accuracy is the top priority, further utilize Yao's garbled circuit and the homomorphic nature of Hash ElGamal encryption to construct a security evaluation protocol [15].

Specifically, in the sports industry chain, ElGamal encryption system can be used to protect data transmission and sharing among various participants, including manufacturers, suppliers, sellers, consumers, etc. By establishing a data transmission and sharing system based on ElGamal encryption system, functions such as encrypted data transmission, digital signature, random number generation, decryption data access, public and private key management can be achieved. Through the above functions, the data transmission and sharing system based on ElGamal encryption system can achieve data transmission and sharing among various participants in the sports industry chain.

1) ElGamal key generation algorithm. The process of generating public and private key pairs in ElGamal encryption system:

Step 1: After randomly selecting a large prime number  $q$  that meets the security requirements, a generator  $g \in Z_q^*$  of the finite field is generated.

Step 2: After selecting a random number  $x(1 < x < q-1)$  and calculating  $y \equiv g^x \pmod{q}$ , the

public key is  $(y, g, q)$  and the private key is  $x$ .

2) Encryption algorithm. For plaintext  $m \in Z_q^*$ , by randomly selecting integer  $k: 0 < k < q-1$ , the ciphertext  $C = (c_1, c_2)$  is obtained according to calculation Formula (1).

$$\begin{aligned} c_1 &= g^k \bmod q \\ c_2 &= my^k \bmod q \end{aligned} \quad (1)$$

3) Decryption operation. For ciphertext  $C = (c_1, c_2) \in Z_q^* \times Z_q^*$ , plaintext  $m$  is decrypted using private key  $x$  through Formula (2).

$$m = c_2 (c_1^x)^{-1} \bmod q \quad (2)$$

### 3.2. Distributed ElGamal Encryption System

Distributed ElGamal encryption system is a variant of ElGamal encryption system, which has many advantages and advantages, and is widely used in electronic auctions, electronic voting, and multi-party majority sorting.

1) Key generation algorithm. If  $q$  is a large prime number and  $g$  is the generator of group  $Z_q^*$ . It is assumed that there are  $n$  participants  $q_1, q_2, \dots, q_n$ , each participant  $q_i (i=1, 2, \dots, n)$  generates their own public-private key pairs  $s_i$  and  $h_i$  based on the ElGamal public key encryption system and publicly publishes public key  $h_i$ , where  $h_i \equiv g^{s_i} \bmod q$ . Therefore, the public encryption public key generation algorithm is Formula (3), while the main private key generation algorithm is Formula (4).

$$h = \prod_{i=1}^n h_i \bmod q = g^{\prod_{i=1}^n s_i} \bmod q \quad (3)$$

$$s = \sum_{i=1}^n s_i \bmod q \quad (4)$$

2) Encryption algorithm. For message  $m$ , a random number  $k$  is selected, where  $1 < k < q-1$  and  $\gcd(k, q-1) = 1$ , the encryption algorithm is:

$$E_h(m) = (x, y) = (g^k \bmod q, mh^k \bmod q) \quad (5)$$

3) Decryption algorithm. In this algorithm, each participant can decrypt ciphertext  $(x, y)$  without reconstructing the primary and private key  $s$ . The specific steps are as follows: each participant  $q_i$  calculates  $x^{s_i}$  and restores the following plaintext:

$$D(y, x^{s_1}, x^{s_2}, \dots, x^{s_n}) = y / \prod_{i=1}^n x^{s_i} \bmod q = y / x^{\sum_{i=1}^n s_i} \bmod q = m \quad (6)$$

The distributed ElGamal encryption system allows the main and private keys to be shared among participants, and can be decrypted without reconstructing the main key. Moreover, this system does not require specialized institutions to distribute private keys, and utilizes the homomorphic characteristics of the ElGamal encryption system. Finally, when calculating the results of votes, the feature of self counting can be achieved, and trusted third-party counting institutions can be replaced by smart contracts.

## 4. Comparative Experiment on Quality Traceability and Credibility Assurance System

### 4.1. Sports Industry Classification

There has always been no consensus on the concept of "sports industry". Scholars generally hold an ambiguous attitude towards the concept of the sports industry and believe that as long as it is related

to sports, it can be considered as the sports industry. Some scholars defined “sports industry” from the perspective of “activity set theory”, and defined “sports industry” as “all industry activities related to sports” set theory. Some scholars have proposed the concept of the sports industry from the perspective of “enterprise groups” and defined it as “enterprise groups”. Currently, the Sports Science Society has defined a concept for the sports industry: Sports and related industries are industrial activities that provide sports products and services to the public, as well as the collection of industrial activities related to these activities. This definition expands the scope of “sports industry”, which is currently a more formal and authoritative definition. Therefore, with the help of the definition of this concept, a classification table for the sports industry is formulated, as shown in Table 1.

**Table 1.** Classification of the Sports Industry

| Serial number | classification                          | content                                                                                                       |
|---------------|-----------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 1             | Sporting goods production               | Sportswear, sports shoes, sports equipment, sports bags, etc.                                                 |
| 2             | Organization of sporting events         | Organization and operation of domestic and international sports events                                        |
| 3             | Construction of stadiums and facilities | Investment in the construction and facilities of stadiums, stadiums and other venues                          |
| 4             | Sports marketing and advertising        | Marketing and advertising promotion of sporting events, celebrities and brands                                |
| 5             | Sports tourism                          | Tourism for the purpose of watching competitions and participating in sports activities                       |
| 6             | Sports training and education           | Physical education, physical education, physical research, etc.                                               |
| 7             | Sports media and digitization           | Application of sports news, sports media, and digital technology in the field of sports                       |
| 8             | Sports health and Rehabilitation        | The health promotion effect of physical education and the application of exercise in rehabilitation treatment |
| 9             | Sports culture and creativity           | Sports-themed cultural, artistic, creative works, etc.                                                        |

According to Table 1, the sports industry has roughly formed an industrial system consisting of production of sports goods, organization of sports events, construction of sports venues and facilities, sports marketing and advertising, sports tourism, sports training and education, sports media and digitization, sports health and rehabilitation, sports cultural creativity, and other industrial chain links.

#### 4.2. Experimental Design

Determination of research objectives and research questions: This article aimed to explore blockchain technology to provide new solutions for quality traceability in the sports industry chain, thereby improving the credibility of the sports industry.

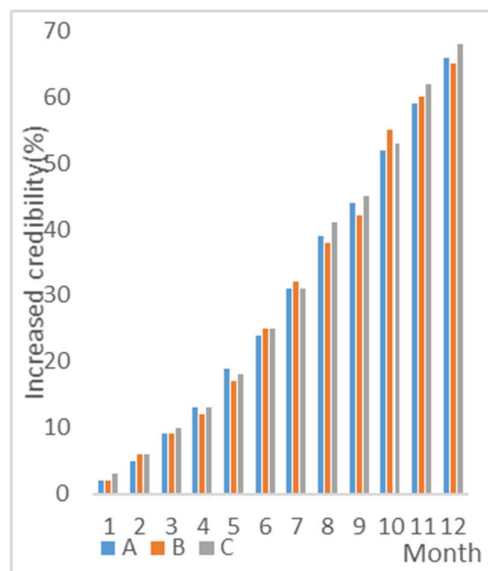
Determination of experimental object: A sports enterprise was selected as the experimental object, and a quality traceability and credibility assurance system was established.

Determination of experimental group (group a) and control group (group b): The experimental subjects were divided into group a and group b. Group a used the sports industry quality traceability and credibility assurance system based on blockchain technology development architecture (this system), while group b used the traditional sports industry quality traceability and credibility

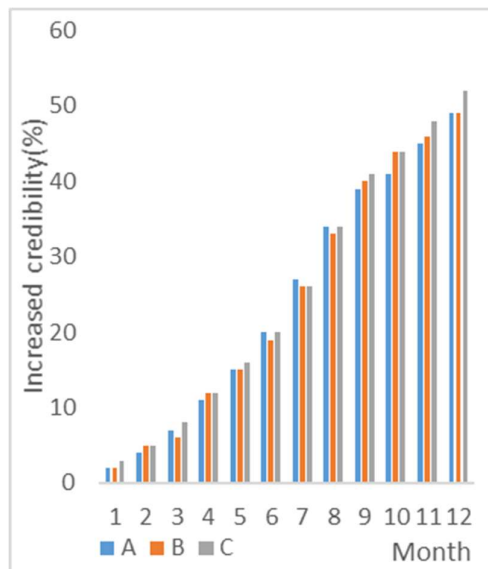
assurance system (traditional system).

1) Reliability improvement test. Credibility refers to the degree to which an information or thing is considered true and reliable. In the information age, credibility is particularly important because accurate information can guide people to make the right decisions, while inaccurate information may lead to incorrect decisions and even endanger people's lives and property safety. When evaluating the credibility of an information, multiple aspects need to be considered, such as source reliability, information consistency, and whether facts can be confirmed.

Improving the credibility of quality traceability systems is of great significance for ensuring data security and protecting the interests of users. This article conducted experiments on the credibility of two systems in the A, B, and C sports industries, and recorded a comparison of the system's credibility improvement. The data is shown in Figure 3.



(a) Improvement Rate of the System in this Article



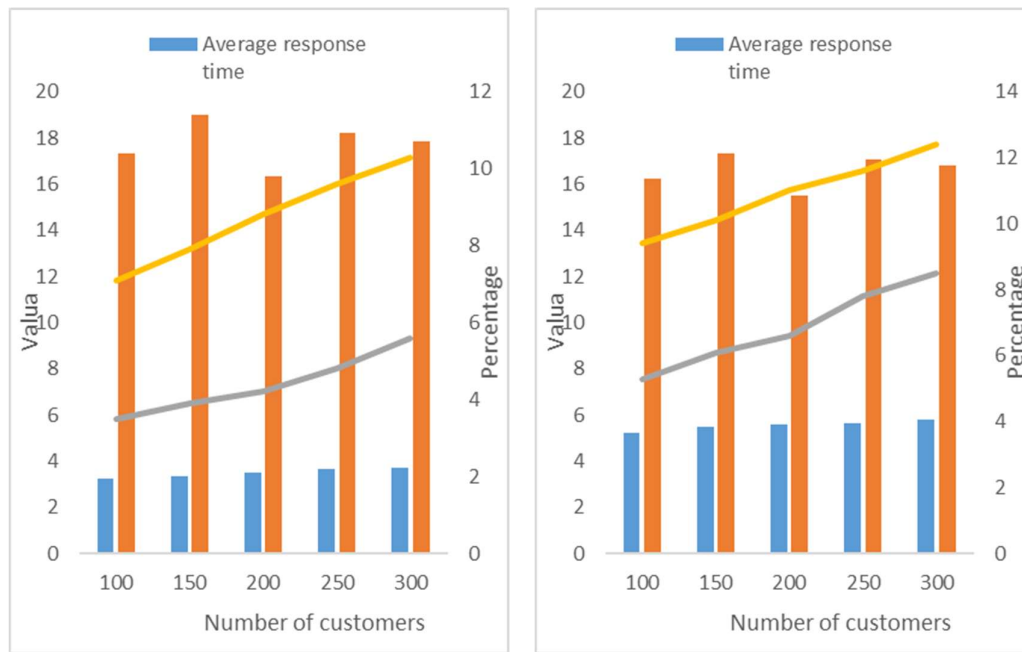
(b) Improvement Rate of Traditional Systems

**Fig. 3.** Reliability Improvement Rate

In Figure 3 (a), it can be seen that after running the system for one month, the credibility of the A and B sports industries increased by 2%, and the credibility of the C sports industry increased by 3%; running for 12 months increased the credibility of sports products A, B, and C by 66%, 65%, and 68%, respectively. In Figure 3 (b), the traditional system increased the credibility of the A and B sports industries by 2% and the C sports industry by 3% after running for one month; the 12 months operation increased the credibility of the A and B sports industries by 49%, and the credibility of the C sports industry by 52%. From Figure 3, it can be seen that people's trust in the sports industry is gradually increasing, but this system is more conducive to improving the trust of the sports industry compared to traditional systems.

2) Performance testing. Performance testing refers to the process of testing and evaluating the performance of a software system under a certain load. Performance testing is one of the important means to ensure the performance of software systems. Through performance testing, system bottlenecks and problems can be identified, and corresponding solutions can be proposed to

improve system performance and reliability. This article conducted parallel testing on two systems and recorded performance indicators such as response time/s, transmission data Mbps, CPU (Central Processing Unit) utilization, and memory utilization when the number of parallel clients was 100, 150, 200, 250, and 300. The test data is shown in Figure 4.

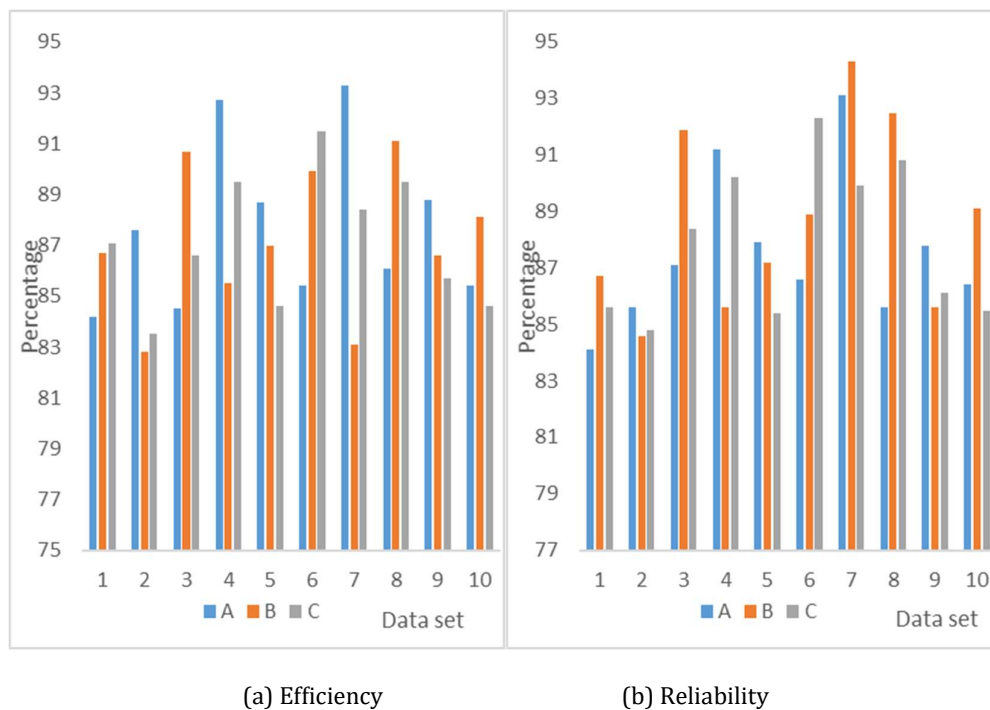


(a) System Testing Situation in this Article (b) Traditional System Testing Situation

**Fig. 4.** Parallel Testing Situation

In Figure 4 (a), the average response time of the system in this article was within 4 seconds, and the transmission data was between 16-20 Mbps; CPU utilization and memory utilization were below 6% and 11%. According to Figure 4 (b), the average response time of traditional systems was within 6 seconds, and the transmission data was between 15-18 Mbps; CPU utilization and memory utilization were below 9% and 13%. From Figure 4, it can be seen that compared to traditional systems, the system in this article has shorter response time, faster data transmission, lower CPU utilization and memory usage, indicating that blockchain technology is beneficial for improving the performance of the sports industry quality traceability system.

3) Quality traceability efficiency and reliability. Quality traceability can help teams understand the quality status of products or projects, and timely identify and solve existing problems. This can ensure that the final delivered products or projects meet the expected quality requirements. The improvement of efficiency and reliability can effectively improve the results of quality traceability. This article designed ten experimental data, ranging from 1 to 10, and compared the efficiency and reliability improvement of A, B, and C sports industries, as shown in Figure 5.



**Fig. 5.** Efficiency and Reliability Improvement Ratio of the System in this Article

In Figure 5 (a), when using the system in this article, the efficiency of the A sports industry improvement was the lowest at 84.2% and the highest at 93.3%; the B sports industry had a minimum of 82.8% and a maximum of 91.1% in group 2; the lowest efficiency of the C sports industry was 83.5, and the highest was 91.5. In Figure 5 (b), it can be seen that the reliability improvement of the A sports industry was 84.1% at the lowest and 93.1% at the highest; the lowest reliability improvement in the B sports industry was 84.6%, and the highest was 94.3%; the lowest reliability improvement in the C sports industry was 84.8%, and the highest was 92.3%. According to Figure 5, the efficiency and reliability of the system in this article were improved by 80% -95%.

## 5. Conclusions

This article studied the application of blockchain technology in the sports industry chain and proposed a quality traceability and credibility assurance system based on blockchain technology. The system used distributed ledger technology to record the production, circulation, and consumption records of sports products, and achieved automated quality detection and transaction verification through smart contracts. Experiments have shown that this system can improve the quality and credibility of sports products, and promote the healthy development of the sports industry. The research results of this paper are of great significance for solving the problems of quality traceability and credibility in the sports industry chain, and for promoting the Digital transformation and innovative development of the sports industry. The application of blockchain technology in the sports industry chain can continue to be explored in depth in the future to make greater contributions to the sustainable development of the sports industry.

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