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Research on Wine Supply Chain Traceability based on Blockchain

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Abstract

Taking the wine traceability system as an example, this paper establishes a sound wine safety traceability system to ensure the authenticity and reliability of the data generated in each link of the supply chain. By analyzing the problems in the operation of the current wine supply chain traceability system, including the collection and input of data in each link of the supply chain and the centralization of the supply chain traceability system, the consensus algorithm of Ethereum blockchain is improved. Use Ethereum smart contract to propose a blockchain based solution and framework for traceability and visibility of wine supply chain. Propose, implement and test smart contract algorithms that manage and ensure appropriate interaction among key stakeholders in the wine supply chain.

Keywords

Blockchain Technology, Wine Traceability, Supply Chain, Consensus Mechanism.

1. Introduction

In recent years, with the development of economic globalization and Internet technology, people's material life has been improved, and consumers' demand for basic necessities has been increasing, thus opening a new consumption era. In the past, wine was generally a symbol of luxury goods. Now people are rich, and wine has become a popular table consumer goods. The emergence of new technologies and new models has brought great changes to the wine industry and increased market competition and opportunities. At the same time, the popularity of e-commerce has narrowed the distance between importers and consumers, which makes wine prices lower. The huge Chinese wine market has also attracted a large number of wine sellers at home and abroad to actively layout the wine industry in the commercial market, further stimulating the development of market quality and wine production. However, China's wine market is chaotic. Due to the fierce occupation of the wine market at home and abroad, fake goods under the temptation of high profits, people's misunderstanding of wine and so on. International winemakers, wineries and domestic wine companies are looking for a place in China's wine market. How can wine merchants solve many contradictions in the Chinese market, enhance consumer confidence, solve the problem of wine fraud, and safeguard their own image and brand interests.

Because fake liquor brings huge profits, fake and shoddy liquor has always been the most serious problem in the liquor industry, and the probability of high-grade liquor being forged is the greatest. For enterprises, the spread of counterfeit products not only damages the brand image of enterprises, but also brings huge economic losses to enterprises. Therefore, enterprises need an effective and reliable anti forgery method to protect their interests. For individuals, fake wine is extremely harmful to human body. Consumers urgently need to track the production and logistics information of products through practical and effective technical means. The current wine supply chain covers all aspects of commodity production and circulation, from raw materials to finished products, from marketing to consumers. If the relevant information is destroyed, it is difficult to trace the cause of the incident or investigate the responsibility of the accident. In addition, centralized data management methods create information islands, increasing data processing risks, management challenges and costs.

Nakamoto introduced the concept of blockchain in 2008. Blockchain began to receive the attention of social departments in 2014 and peaked in 2017. It is one of the most popular research directions in the Internet field. Blockchain is a distributed technology, which has the characteristics of low cost, high efficiency, security and reliability; Each node in the blockchain has a registry copy recording all system transaction information. Each node can verify the transaction information of the whole network, reflecting the characteristics of decentralization [1]. Bitcoin [2] uses the pow mechanism to ensure that the blockchain is always stored on a valid string without bifurcation. Therefore, in order to process node information, at least 51% of the nodes in the blockchain must be captured. However, by 2016, the total computing power of the bitcoin system exceeded the sum of the world's top 50 supercomputers. Therefore, when the number of nodes reaches a certain size, it is almost impossible to unilaterally change the blockchain information.

Blockchain technology has a wide range of applications: phase 1.0 of blockchain is characterized by the issuance of cryptocurrency; Phase 2.0 of blockchain is characterized by the development of smart contracts; Phase 3.0 of blockchain is dominated by enterprise operation system (EOS). The most mature and reliable technology is the research and application of blockchain phase 2.0, which mainly involves the application of blockchain technology in fields other than digital currency, such as Internet, asset verification, etc. Considering the current technology research and application trend, data block chain technology should be widely used in the Internet field of objects, especially in the traceability of sensitive products, which will greatly improve the authenticity, integrity and reliability of monitoring data [3].

2. Literature References

We review and highlight the literature related to blockchain applications in the food and agriculture supply chain. While the literature on blockchain applications in the banking, finance and insurance industries has been steadily growing, the literature on food and agriculture is scarce and just beginning to gain popularity. Blockchain emerged as a new distributed information technology; it represents a new approach in the field of supply chain, where visibility and transparency of product flows are the main challenges. In 2017, Daniel et al [4] proposed the concept of applying blockchain technology to secure information in the food supply chain, but it has not yet been implemented. Iansiti et al [5] proposed a blockchain-based wine traceability chain . The transaction is visible to wine chain participants such as viticulture, wine processing, logistics, and consumption because it provides secure, transparent, and accurate information sharing. Their study shows that the application of blockchain-based traceability system facilitates the traceability of agri-food products. Toyoda et al [6] created a blockchain smart contract model for supply chain management using Ethernet architecture. They also designed an item-level smart contract to manage event information for products in the supply chain. Galves et al [7] reviewed the challenges and potential uses of blockchain in ensuring traceability and authenticity in the food supply chain. Kamilaris et al [8] examined the impact of blockchain technology in agriculture and food supply chains, presented existing ongoing projects and initiatives, and discussed overall impact, challenges, and potential, providing a critical view of the maturity of these projects. Rita et al [9] describe how blockchain can be integrated into supply chain architectures to create a reliable, transparent, trustworthy, and secure system. Reno et al [10] examine the main approaches to food traceability that exist today and propose the use of blockchain and product identifiers to achieve a more reliable food traceability in a restaurant prototype. AFFAF SHAHID et al [11] provide a complete solution for blockchain for agriculture and food (agri-food) supply chain. It utilizes the key features of blockchain and smart contracts, deployed on an Ethernet blockchain network. Zhao et al [12] reviewed the recent advances in blockchain technology, the main applications in the agricultural supply chain, and the challenges faced from a holistic perspective through a systematic literature network analysis.

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The combination of blockchain and IoT provides a feasible solution for quality monitoring and traceability in the food supply chain. In 2016, Tianfeng et al [13] constructed a traceability system for the agricultural products supply chain based on blockchain and radio frequency identification (RFID) technology. The system realized automatic collection and storage of information through the radio frequency identification system and blockchain technology. In order to develop a feasible solution for a blockchain-based traceability system, major issues must be addressed, including data explosion, trust transfer, and sensitive information disclosure in blockchain. Tian proposed a hazard analysis and critical control point (HACCP)-based food supply chain traceability using IoT in [14]. Previously, Tian discussed the advantages and disadvantages of RFID for agrifood supply chain traceability in [15]. In 2018, Miguel [16] proposed the AgriBlockIoT solution, which integrates IoT and blockchain technologies to implement a food traceability system by Ethereum and Hyperledger sawtooth. AgriBlock IoT can provide data transparency, fault tolerance, invariance, and auditability for agri-food traceability systems. Caro et al [17] proposed a blockchain-based AgriBlock IoT traceability solution that integrates data from IoT devices along the value chain. They developed a use case to track products from farm to fork and compared the implementations through Ethereum and Hyperledger. Mondal et al [18] proposed a blockchain-based IoT architecture to create a transparent food supply chain. The architecture is implemented by integrating radio frequency identification (RFID) based sensors at the physical layer and blockchain at the network layer. RFID provides unique identification of product and sensor data which helps in real time quality monitoring. The blockchain architecture helps to create a tamper-proof digital database of food packages in each instance. Hongning Dai et al [19] studied the integration of blockchain technology with the Internet of Things. They called this synthesis of blockchain and IoT as "blockchain of things" (BCoT). Chanson et al [20] proposed a design theory for a blockchain-based sensor data protection system (SDPS), including requirements, design principles, and features, which utilizes data authentication. Tsang et al [21] proposed a blockchain IoT-based food traceability system (BIFTS) that integrates new deployment of blockchain, IoT technology and fuzzy logic into a fully traceable shelf-life management system for perishable foods. Shipment transit times, stakeholder assessments, and shipment volumes are considered. Blockchain data flow is then aligned with the deployment of IoT technology based on the level of traceable resource units. Finally, reliable and accurate data are used for shelf-life adjustment and fuzzy logic is used for quality decay evaluation to establish decision support for the food supply chain. Qijun Lin et al [22] proposed a food safety traceability system based on blockchain and EPC information services and developed a prototype system. The management architecture of on-chain and off-chain data is proposed, and the data explosion problem of IoT blockchain can be mitigated by the traceability system. In addition, enterprise-level smart contracts aim to prevent data tampering and sensitive information leakage during the information interaction between participants. The prototype system was implemented on the Ethernet platform. According to the test results, the average time for information query response is about 2 ms, while the on-chain data volume and query count are 1 gb and 1000 times/s, respectively. Since the existing infrastructure cannot accommodate the data of goods in transit in the supply chain for real-time transmission, Jangirala et al [23] designed a new 5G-enabled Internet of Things (IoT) mobile edge computing environment based on lightweight block chain-based radio frequency identification (RFID) authentication protocol that provides better performance in terms of security and functionality, communication and computational overhead. Sen Zhang et al [24] proposed a blockchain technology solution for the cold chain logistics industry, which utilizes the features of blockchain as well as IoT technology to improve the trustworthiness and data security in the cold chain logistics industry.

The provenance and traceability of food products is crucial in distribution and transportation networks to ensure the integrity of food labels and the effective management of quality and contamination issues. Significant problems in terms of cost, quality and health issues may arise without sufficient visibility. Haya et al [25] proposed a decentralized proof-of-delivery system that uses Ether smart contracts to prove the delivery of shipped items between the seller and the buyer without bothering about how many intermediate transporters, and also incorporates an arbitration mechanism if disputes

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arise during the transportation process. Zhang Gang [26] uses Jiangsu Bamboo reed valve industry as an example to introduce blockchain technology in the logistics chain to speed up the product flow, while also improving the security of transactions, increasing the transparency of logistics and transportation, reducing the cost of building central servers and manpower overhead, and solving problems in the existing logistics operation process of the enterprise. pal and Kant [27] illustrate the use of emerging blockchain technology to improve IoT food logistics. Gao Yanchen [28] started from the logistics information tracing mechanism under the Internet crowdsourcing model, applied blockchain technology to the whole chain of logistics information tracing, and studied the logistics information tracing mechanism based on blockchain technology by using blockchain underlying technology, principal-agent theory and incentive theory. The data information asymmetry problem and trust problem are solved. Quentin Betti et al [29] present the recent progress of blockchain and smart contracts in hyper-connected logistics applications and concrete implementation through a simulation platform. Alexandre Dolgui et al [30] propose a new model for the smart contract design problem of multiple logistics service providers in a supply chain and conduct tested, and the results show that the problem can be described as a multiprocessor flexible flow shop scheduling problem. The use of state control variables in the model allows operational state updates in the blockchain, which in turn provides automatic information feedback, disruption detection and contract execution control.

It is clear from this related literature work that there is a growing trend towards the adoption of blockchain technology to enhance information security, transparency and authentication of various standards in the food supply chain, and that the combination with the Internet of Things is an added bonus. A large body of literature discusses the conceptual application of blockchain in the supply chain, but lacks a concrete framework or approach for implementation. Our article aims to highlight the important features of this emerging technology using smart contracts.

3. Wine Supply Chain Traceability Model based on Blockchain

Grain supply chain traceability (gsctm) model can be used to standardize internal source events and enterprise specific demand source data in food supply chain. Gsctm consists of three object types, four event node types and three relationship edge types. It uses all supply chain events as a guide to describe the five-dimensional traceability data generated by the internal traceability process.

Objects and object classes represent all objects or digital entities involved in supply chain events, such as vehicles, work units, files, sensors, people, companies, etc. And can form a value pair - the key of the attachment object node attribute set. The gsctm scheme is shown in Fig. 1:

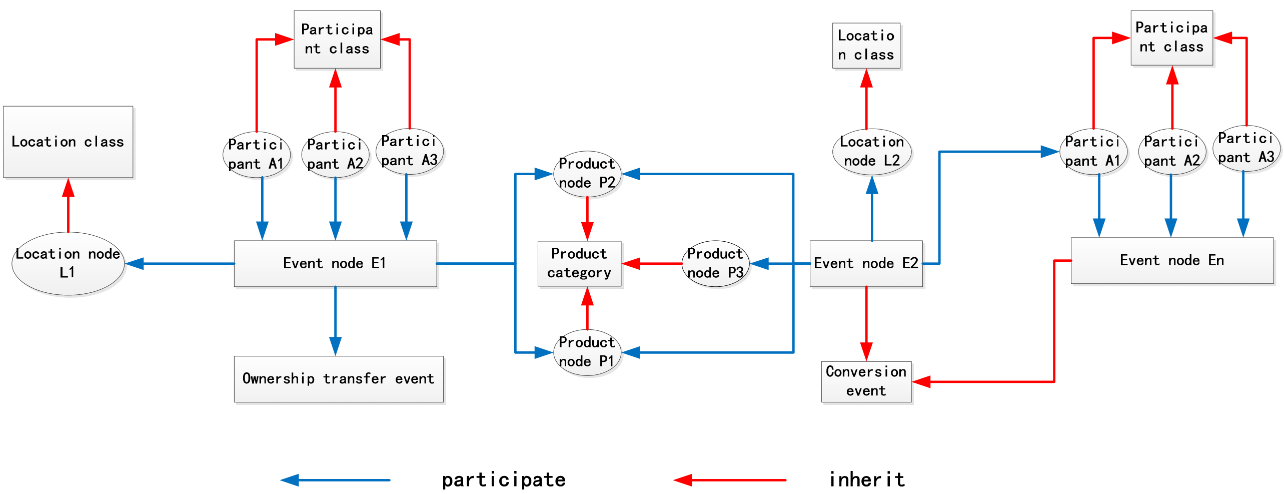

Fig. 1. Schematic diagram of gsctm model

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In this paper, three types of Object Class nodes are designed.

(1) Participant nodes that describe the participant dimension of the retrospective data. A is the Actor abbreviation and N is the number of participants. For example, A1 represents the source participating companies and A2 represents the participating companies in the target.

(2) The "location" used to describe the traceability data is represented by Ln, which stands for Location, and n indicates that the event may have two locations to be described, e.g., L represents the location of the receiving product and L2 represents the geographic location of the company.

(3) The category node, which is used to describe the traceable product dimension information in the traceability data. p represents the product abbreviation and n represents all product information related to time.

Event and event classes are used to classify and summarize all events that occur in the wine supply chain and create a set of key-critical pair attributes for the event nodes. Four event nodes were designed.

(1) Transportation event class describing the change in location of physical or digital participants in the wine supply chain. It is represented by Tp-En, Tp for the Tranport abbreviation, e for the Event abbreviation, and n for the event abbreviation within the enterprise. the higher the value of n, the later the event occurs.

(2) The conversion event class that describes the event that converts one or more objects to a new object. The higher the value of n, the later the event sequence. Transformation activities, such as wine processing, which requires the transformation of additives and coarse grains into product food; in the packaging and transportation of wine, many box-level logistics units are packed and packaged at the highly aggregated pallet level at the logistics unit level, which is also a typical transformation event.

(3) Categories of observation events describing various observation activities, such as the use of sensors and weather stations to monitor the temperature and humidity of the vitrification process. Represented by Ob-En, Ob is the abbreviation of Observation, e is the abbreviation of Event, and n is the order in which the events occur in the enterprise. the larger the value of n, the later the event occurs.

(4) Ownership transfer event category that describes the ownership or change of ownership of an object. For example, sales is the type of ownership transfer event, denoted by Ot-En, where Ot is the abbreviation of Ownership transfer, e is the abbreviation of Event, and n indicates that the events occur in the order of events within the company. the larger the n, the more events occur in the following order.

Edges are used as associative links between event nodes and object nodes in order to create a set of key-attribute pairs for connected edges. There are three types of connected edges.

(1) Inheritance links used to connect nodes to node-type nodes (denoted by In1a E), In being an abbreviation for Inheritance and e being an abbreviation for Edge.

(2) Participation links for connecting object nodes to event nodes (denoted by INV-En), where INV is an abbreviation for Involvement, e is an abbreviation for Edge, and n is the number of participating edges. For example, in the case of wine growing, the farmer participates as a node in the growing activity

(3) State linkage, which allows to associate two object nodes in a specific way, using St-En, St for State abbreviation, e for Edge abbreviation, and n for the number of state links. For example, in the case of a growing company, the farmer is a node of the participant and the growing company is a node of the participant. A bidirectional state link must be established between them. Status names being used/being used.

In the wine supply chain, it is assumed that the company must take the following steps: buy produce (purchase), grow grapes (plant), collect crop data (harvest), collect wine (harvest), sell wine

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(purchase), and ship wine (ship). Growing companies must follow these six steps to deliver their grain to intermediate and middle companies in the supply chain.

4. Implementation Framework

As mentioned above, the planting base has created a smart contract to breed and cultivate grapes, and then sell the bred grapes to the winery. The following is a detailed algorithm:

Algorithm 1 grape planting process and sales

```
Input: list of registered wineries
Name of planting base, grape variety and grape price
1. Blockchain creation
2. Create a grape parcel code and record the information of each parcel
3. If tree age between X1 and X2 then
    Return grapes are suitable for making wine and marking
else
    Return grapes are not suitable for making wine
4. If irrigation between 5 and 8 times a year
The sequence of irrigation time is soil water, pre flower water, post flower water, berry swelling water and berry coloring
Water, buried soil and cold proof water then the irrigation time is qualified
Elif records the information of irrigation source, water quality, irrigation method and irrigation amount
    return True
else
    return Error
5. If fertilizing between 3 and 4 times a year
The sequence of fertilization time is post excavation, berry expansion stage and berry color conversion stage
Then the fertilization time is qualified
Elif records the information of fertilizer source, fertilizer name, fertilization method, fertilization amount and dilution ratio
    return True
else
    return Error
6. If pest control between 5 and 7 times a year
Elif was not sprayed with pesticide 20 days before picking
    return True
else
    return Error
If the names of diseases and insect pests, pesticide manufacturers, names of applicable agents and main components of agents are recorded
Dilution ratio, spraying method and control effect information
    return True
```

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```
    else
        return Error
    else return Error
    7. If recorded the variety name, harvest time, berry sugar content, acidity, 100 grain weight and
production certificate information
        Return the grapes are ready
    else
        return Error
    8. Restrict access to the list of registered processing plants only
    9. Wineries send requests for grapes
    10. If winery = registered and grape price = payment
         Return the contract status is changed to submit
    The processing plant status is changed to waiting for grapes
    The planting base agreed to sell grapes
    Message notification, statement of grape sales
    else
        return Error
```

Algorithm 2 wine processing and sales

```
    Input: the blockchain address of the winery
    List of distributors registered
    Block chain address of distributor area
    List of retailers registered
    Retailer's blockchain address
    Grape quantity, purchase date and purchase price
    1. Record the grape stem removal and pressing and enter the fermentation tank
    2. If the first fermentation time between 10 days and 12 days
        Return the first fermentation time is qualified and the first fermentation is over
    else
        Return the first fermentation time is unqualified
    3. If recorded grape variety, fermentation temperature range, sugar content, acidity, alcohol
content of grape juice, name, type and concentration of auxiliary materials
        return True
    else
        return Error
    4. If the peel and other impurities precipitated by the first fermentation were cleaned
        return True
    else
        return Error
    5. The grape juice is pumped to another fermentor for the second fermentation
```

6. If recorded the fermentation time, fermentation temperature range, wine precision of grape juice, total sugar, total acid, total sulfur dioxide, dry leaching substances, bottling time, name, dosage form and concentration of excipients

Return wine is ready

else

return Error

7. Restricted access is limited to the list of registered distributors only

8. Distributors send requests for wine

9. If distributor = registered and payment status = completed

Return the contract status is changed to wine request

Distributor status changed to waiting for wine

The winery agreed to sell wine

Notification of wine sales

else

return Error

10. Restrict access to the list of registered retailers only

11. Retailers send requests for wine

12. If retailer = registered and payment status = completed

Return the contract status is changed to wine request

Retailer status changed to waiting for wine

The distributor agreed to sell the wine

Notification of wine sales

else

return Error

5. Summary

The main purpose of this paper is to solve the problem of safety traceability of traditional packaged wine. Due to the problems of centralization and information manipulation in the traditional packaged wine traceability system, the authenticity of information in the whole traceability process can not be guaranteed. Therefore, when combining modern blockchain technology to solve the problem of data centralization, we should realize that fault information is not controlled by specific nodes or links in the supply chain. Through the in-depth study of the principle of blockchain technology and the design of wine traceability system, this paper creates a wine supply chain traceability platform based on blockchain technology. Aiming at the wine supply chain scenario, this paper improves the Ethereum blockchain consensus algorithm to meet the needs of supply chain suppliers, ensure that the supply chain platform has the ability of rapid response and data security, and reduce the resource consumption in the supply chain. In the future, we plan to integrate automated payment and proof of delivery into our proposed solution, that is, after the successful physical delivery of crops and products, the smart contract uses cryptocurrency to pay all parties automatically and centrally.

References

[1] Yang Tian, Zhigang Chen, Xinxia Song, et al. Application overview of blockchain in supply chain management [J / OL]. Computer engineering and application. 2021, p.1-18.

[2] Yong Dai. Decision analysis on the use of Traceability Technology in food enterprises based on the influence of supply chain stakeholders -- Taking blockchain as an example [J]. Supply chain management. 2021,2 (07), p. 74-82.

[3] Zusheng Cao, Lei Ding. Research and design of agricultural products supply chain traceability system based on hyperledger sawtooth [J]. Modern computer, 2021 (18): 156-162.

[4] Daniel Tse, Bowen Zhang, Yuchen Yang, Chenli Cheng, Haoran Mu. Blockchain Application in Food Supply Information Security[J]. Proceed-ings of the 2017 IEEE Ieem, 2017: 1357-1361.

[5] Lansiti M, Lakhani, KR. The truth about blockchain[J]. Harvard Business Review, 2017, 95(1):118-127.

[6] Toyoda K, Mathiopoulos PT, Sasase I, & Ohtsuki T. A novel blockchain-based product ownership management system (POMS) for anti-counterfeits in the post supply chain[J]. IEEE Access,2017, 5:17465-17477.

[7] Galvez, J. F, Mejuto, J. C, Simal-Gandara, J. Future challenges on the use of blockchain forfood traceability analysis[J]. TrAC Trends in Analytical Chemistry, 2018, 107: 222-232.

[8] Kamilaris, A, Fonts, A, Prenafeta-Boldú, F.X, The Rise of Blockchain Technology in Agriculture and Food Supply Chains[J]. Trends in Food Science & Technology, 2019,640-652.

[9] Rita Azzi, Rima Kilany, Maria Sokhn. The power of a blockchain-based supply chain[J]. Computers& Industrial Engineering, 2019, 135: 582-592.

[10] Reno, Varghese George, Hari Om Harsh, Papri Ray, Alex K. Babu. Food Quality Traceability Prototype For Restaurants Using Blockchain And Food Quality Data Index[J]. Journal of Cleaner Production, 2019:240.

[11] Shahid A, Almogren A, Javaid N, Al-Zahrani FA, Zuair M, Alam M. Blockchain-Based Agri-Food Supply Chain:A Complete Solution[J].IEEE Access, 2020, 8: 69230-69243.

[12] Guoqing Zhao, Shaofeng Liu, Carmen Lopez, Haiyan Lu, Sebastian Elgueta, Huilan Chen, Biljana Mileva Boshkoska. Blockchain technology in agri-food value chain management:A synthesis of applications, challenges and future research directions[J]. Computers in Industry, 2019, 109:83–99.

[13] Feng Tian. An agri-food supply chain traceability system for China based on RFID & blockchain technology[J]. International Conference on Service Systems and Service, 2016.

[14] Tian, F. A supply chain traceability sys-tem for food safety based on HACCP, blockchain &Internet of things. In Service Systems and Service Man-agement (ICSSSM), 2017:1-6.

[15] Tian, F. An agri-food supply chain trace-ability system for China based on RFID & blockchaintechnology. In Service Systems and Service Manage-ment (ICSSSM), 2016: 1-6.

[16] Miguel Pincheira Caro, Muhammad Salek Ali, Massimo Vecchio, Raffaele Giaffreda. Blockchain-based Traceability in Agri-Food Supply Chain Management: A Practical Implementation[J]. IoT Vertical and Topical Summit on Agriculture - Tuscany (IOT Tuscany), 2018.

[17] Caro MP, Ali MS, Vecchio M, Giaffreda R. Blockchain-based traceability in Agri-Food supply chain management: A practical implementation[J]. In IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany), 2018:1-4.

[18] Mondal S, Wijewardena KP, Karuppuswami S,Kriti N,Kumar D,Chahal P. Blockchain Inspired RFID-Based Information Architecture for Food Supply Chain[J]. IEEE Internet of things Journal, 2019, 6(3): 5803-5813.

[19] Dai HN, Zheng ZB, Zhang Y. Blockchain for Internet of Things: A Survey[J]. Internet of things Journal, 2019, 6(5):8076-8094.

[20] Chanson M, Bogner A, Bilgeri D, Fleisch E, Wortmann F. Blockchain for the IoT: Privacy-Preserving Protection of Sensor Data. Journal of the Association for Information Systems, 2019, 20(9): 1274-1309.

[21] Tsang YP, Choy KL, Wu CH, Ho GTS, Lam HY. Blockchain-Driven IoT for Food Traceability With an Integrated Consensus Mechanism[J]. IEEE Access, 2019, 7: 129000-129017.

[22] Lin QJ, Wang HZ, Pei XF, Wang JY. Food Safety Traceability System Based on Blockchain and EPCIS[J]. IEEE Access, 2019, 7: 20698-20707.

[23] Jangirala S, Das AK, Vasilakos AV. Designing Secure Lightweight Blockchain-Enabled RFID-Based Authentication Protocol for Supply Chains in 5G Mobile Edge Computing Environment[J]. IEEE Transactions on Industrial Informatics, 2020, 16(11): 7081-7093.

[24] Sen Zhang, Jian Ye, Guogang Li. Research and implementation of blockchain technology scheme for cold chain logistics [J]. Computer engineering and application2020, 3: 19-27.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202201_8(1).0058

[25] Haya R. Hasan, Khaled Salah. Blockchain-based Proof of Delivery of Physical Assets with Single and Multiple Transporters[J]. Journal of Latex Class Files, 2015, 14(8).

[26] Gang Zhang. Analysis of blockchain technology on enterprise logistics benefits -- Taking Jiangsu Zhuzhou valve industry as an example [D]. Zhejiang University, 2018.

[27] Pal A, Kant K. Using Blockchain for Provenance and T raceability in Internet of Things-Integrated Food Logistics[J]. Computer,2019, 52(12).

[28] Yanchen Gao. Research on logistics information traceability mechanism based on blockchain technology [D]. Zhejiang University of technology, 2019.

[29] Quentin Betti, Raphaël Khoury, Sylvain Hallé. Improving Hyperconnected Logistics with Blockchains and Smart Contracts[J]. IT Professional, 2019, 21(4): 25-32.

[30] Alexandre Dolgui, Dmitry Ivanov, Semyon Potryasaev, Boris Sokolov, Marina Ivanovaband, Frank Werner. Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain[J]. International Journal of Production Research, 2019, 58(7): 218 4-2199.