Blockchain Technology in Agricultural Products and Food Applications

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Compared with the traditional centralized information supervision mode, the application of blockchain as a new scientific and technological innovation technology in the management of agricultural products and food supply chain can promote a more refined management of agricultural products and food, and provide feasible ideas for ensuring the quality and safety of agricultural products and food.

precision agriculture   supply chain   blockchain   agricultural products   food safety

1. Introduction

Agricultural scientific and technological innovation is one of the main measures to strengthen the more granular information in the field of agricultural products and food, which can promote the refined supervision of agricultural products and food, and ensure the quality and safety of agricultural products and food [1][2][3][4]. As a decentralized distributed storage ledger technology, blockchain uses the P2P network to broadcast information between nodes to achieve message synchronization of all nodes [5][6]. Multi-blockchain means that multiple blockchains are connected, and the synchronous transmission of messages in each blockchain node is realized through the cross-blockchain mechanism, multi-blockchain consensus mechanism, etc. [7][8]. Applying multi-blockchain to the information management of agricultural products and food supply chains can enhance the performance of blockchains, increase the accounting capabilities of blockchains, and realize the interconnection of multiple links in agricultural and food supply chains. Moreover, it can ensure the non-tampering and traceability protection of information in agricultural and food supply chains, and provide regulators with more accurate and comprehensive information supervision capabilities [9][10][11]. The research on the application of blockchain to agricultural products and food is mainly reflected in the following aspects. First, previous studies have explored the integrated application of blockchain and IoT technology, and explored the use of blockchain decentralization and IoT technology to jointly promote the digital transformation of agricultural and food supply chains [12][13][14]. Second, previous research has investigated the application of blockchain to the information management of different types of agricultural products and food, and provided information management and traceability services for different types of agricultural products and food supply chain structures [15][16][17][18]. Third, previous works have explored the integration and application of blockchain and neural network algorithms, big data technology, identification analysis technology, and other technologies to promote the fine management of agricultural products and food information [19][20][21][22]. Compared with the traditional centralized information supervision mode, the application of blockchain

as a new scientific and technological innovation technology in the management of agricultural products and food supply chain can promote a more refined management of agricultural products and food, and provide feasible ideas for ensuring the quality and safety of agricultural products and food [23][24].

2. Blockchain Technology in Agricultural Products and Food Applications

With the development of blockchain technology, there are increasing numbers of research works on the application of blockchain in the field of agricultural products and food. The research on the application of agricultural products and food is mainly reflected in the theoretical research, architecture improvement, data application, data interaction, and consensus mechanism of blockchain in agricultural products and food supply chains, as shown in **Table 1**. Through the decentralization, traceability, tamper-proof, and other characteristics of the blockchain, the food quality and safety of agricultural products and food supply chains are guaranteed.

Table 1. Research in the field of agricultural products and food based on blockchain.

Category	Main Content	References
Blockchain-based theoretical study of applications in the field of agricultural products and food	Analyze the existing research and study the opportunities and challenges of blockchain research in the field of agricultural products and food.	[25][26][27]
Blockchain-based data application methods in the field of agricultural products and food	Focuses on the use of blockchain to trace and manage agricultural products and food supply chain data.	[28][29][30]
Blockchain-based architecture innovation and improvement research in the field of agricultural products and food	Innovative design and application of new blockchain architecture to improve the scalability of blockchain in agricultural and food applications.	[31][32][33][34]
Blockchain-based research on the trusted interaction of data in agricultural products and food	Research the integrated application of trusted encryption mechanism, Internet of Things technology, etc., with blockchain technology to ensure the trusted interaction of data.	[35][36][37]
Blockchain-based consensus research in the field of agricultural products and food	Research applies to complex requests and efficient consensus among participants in the field of agricultural products and food.	[38][39][40]

In terms of applied theoretical research in the field of agricultural products and food based on blockchain, the research focuses on the opportunities and challenges of blockchain research in the field of agricultural products and food. First, the application of blockchain in the field of agricultural products and food can enhance the sustainability of various agricultural products in three dimensions (i.e., economic, social, and environmental) [25]. Second, blockchain provides technological infrastructure such as digitization, automation, and tracking for

agricultural and food supply chains. It can promote the digital transformation of agricultural products and food [26]. Finally, as a new generation of agricultural digital technology, blockchain can track and identify potential sources of pollution in the agricultural food supply chain [27]. The above research works have conducted quantitative and qualitative analyses through a large number of studies, and described the promotion effect of blockchain in the field of agricultural products and food. However, the supply chain of agricultural products and food is complex, and there are still many challenges in the real large-scale investment of blockchain in the field of agricultural products and food.

In previous works, the application research of blockchain in agricultural products and food has mainly focused on the use of blockchain to trace and manage agricultural product and food supply chain data. For example, Khan et al. proposed an optimized supply chain provenance system for Industry 4.0 in the food industry using state-of-the-art technologies such as IoT, blockchain, and advanced deep learning [28]. Zhang et al. designed a blockchain-based food supply chain security management system, pointing out that the use of blockchain is conducive to reducing management costs and improving management efficiency [29]. The above research pertains to the practical application of blockchain technology to agricultural and food supply chains. However, blockchain still faces many challenges concerning application, e.g., lack of government regulation and lack of trust among agricultural stakeholders in the use of blockchain, etc. [30]. Therefore, there is a need to improve existing blockchains to improve the applicability of blockchains and bring tangible benefits to traditional agricultural and food supply chains.

Therefore, in the previous studies, scholars have conducted research on the innovation and improvement of blockchain-based architecture in the agricultural and food fields. Research focuses on innovative design and application of new blockchain architectures to improve the scalability of blockchain in agricultural and food applications. For example, Leng et al. proposed a public chain of agricultural supply chain system based on double-chain architecture, and mainly studied the double-chain structure and its storage method, resource rent-seeking matching mechanism, and consensus mechanism [31]. Ali et al. proposed a sustainable blockchain framework for the halal food supply chain to overcome challenges related to blockchain implementation [32]. Song et al. proposed a two-blockchain structure including a consensus method, transaction mechanism, sustainability evaluation method, and performance optimization strategy [33]. The proposed structured was used to bring sustainable management practices of all players in to the blockchain network, especially allowing governments to play a more important role in agricultural supply management. Ren et al. proposed a dual-blockchain solution based on the interstellar file system storage for agricultural sampling data protection in IoT (Internet of Things) networks [34]. In summary, to cope with the complex supply chain structure of agricultural products and food, many scholars have begun to explore and improve the existing single-chain blockchain architecture. They use a multi-chain approach to solve the scalability problem of blockchain applications in the field of agricultural products and food, and some results have been achieved. However, the above research merely promotes the applicability of blockchain in the agricultural and food industry. The problem of data security interaction and coarse-grained enhancement of data supervision brought about by the double-chain structure has not been well solved.

In response to the above problems, scholars involved in previous studies have explored the research on trusted interaction of data in the field of agricultural products and food based on blockchain. The research mainly focuses on the integrated application of trusted encryption mechanism, Internet of Things technology and blockchain technology to ensure the trusted interaction of data. For example, Zeng et al. designed an efficient seed quality monitoring and smart water management system using IoT and blockchain technology to manage and coordinate the use of high-quality seeds and water resources in the community [35]. Vangala et al. designed a new authenticated key agreement mechanism envisioned in smart contract-based blockchains in the context of smart agriculture to enhance the persistence and auditability of data stored in blocks [36]. Durga et al. proposed a novel chaotic encryption-based blockchain IoT architecture to ensure data security and privacy in fields such as agriculture [37]. In the practical application of blockchain, the secure interaction of data is conducive to building trust among blockchain users, and the promotion and use of blockchain in the field of agricultural products and food.

Scholars have also conducted research on blockchain-based blockchain consensus in the field of agricultural products and food, which is used to improve the applicability of blockchain in the field of agricultural products and food. The research focuses on efficient consensus applicable to complex requests and participants in the agricultural and food sector. Xu et al. combined blockchain technology and wireless network technology to build a blockchain platform, combined with raft algorithm and PBFT algorithm to design an RBFT consensus mechanism to achieve "accurate identification" of poor people in agriculture [38]. Hu et al. used the immutability of blockchain and the paradigm of edge computing to build a trust framework for organic agricultural supply chains [39]. In addition, according to the organic agriculture supply chain scenario, all stakeholders are divided into four roles, and a new consensus mechanism is proposed to manage the information flow. Wang et al. proposed a practical Byzantine fault-tolerant consensus algorithm to score the credit of enterprise nodes in the rice supply chain, optimize the selection strategy of master nodes, and ensure high efficiency and low cost [40]. The blockchain consensus mechanism is one of the core mechanisms of the blockchain. Designing or improving the consensus mechanism to improve the performance of the blockchain is one of the means to improve the application efficiency of the blockchain in the field of agricultural products and food.

References

1. Bai, C.; Sarkis, J. A supply chain transparency and sustainability technology appraisal model for blockchain technology. Int. J. Prod. Res. 2020, 58, 2142–2162.

2. Zhou, Z.; Wang, B.; Dong, M.; Ota, K. Secure and Efficient Vehicle-to-Grid Energy Trading in Cyber Physical Systems: Integration of Blockchain and Edge Computing. IEEE Trans. Syst. Man Cybern. Syst. 2019, 50, 43–57.

3. Saad, M.; Qin, Z.; Ren, K.; Nyang, D.; Mohaisen, D. e-PoS: Making Proof-of-Stake Decentralized and Fair. IEEE Trans. Parallel Distrib. Syst. 2021, 32, 1961–1973.

4. Yu, H.; Li, H.; Mao, D.; Cai, Q. A domain knowledge graph construction method based on Wikipedia. J. Inf. Sci. 2021, 47, 783–793.

5. Peng, X.; Zhang, X.; Wang, X.; Li, H.; Xu, J.; Zhao, Z. Multi-Chain Collaboration-Based Information Management and Control for the Rice Supply Chain. Agriculture 2022, 12, 689.

6. Tao, Q.; Cai, Z.; Cui, X. A technological quality control system for rice supply chain. Food Energy Secur. 2022, e382.

7. Egala, B.S.; Pradhan, A.K.; Badarla, V.; Mohanty, S.P. Fortified-Chain: A Blockchain-Based Framework for Security and Privacy-Assured Internet of Medical Things with Effective Access Control. IEEE Internet Things J. 2021, 8, 11717–11731.

8. Pavithran, D.; Al-Karaki, J.N.; Shaalan, K. Edge-based blockchain architecture for event-driven IoT using hierarchical identity based encryption. Inf. Process. Manag. 2021, 58, 102528.

9. Peng, X.; Zhang, X.; Wang, X.; Li, H.; Xu, J.; Zhao, Z.; Wang, Y. Research on the Cross-Chain Model of Rice Supply Chain Supervision Based on Parallel Blockchain and Smart Contracts. Foods 2022, 11, 1269.

10. Liu, Y.; Ma, X.; Shu, L.; Hancke, G.P.; Abu-Mahfouz, A.M. From Industry 4.0 to Agriculture 4.0: Current status, enabling technologies, and research challenges. IEEE Trans. Ind. Inform. 2020, 17, 4322–4334.

11. Peng, S.; Hu, X.; Zhang, J.; Xie, X.; Long, C.; Tian, Z.; Jiang, H. An Efficient Double-Layer Blockchain Method for Vaccine Production Supervision. IEEE Trans. NanoBiosci. 2020, 19, 579–587.

12. Rachakonda, L.; Bapatla, A.K.; Mohanty, S.P.; Kougianos, E. SaYoPillow: Blockchain-Integrated Privacy-Assured IoMT Framework for Stress Management Considering Sleeping Habits. IEEE Trans. Consum. Electron. 2020, 67, 20–29.

13. Cox, M.S.; Gerard, P.D. Changes in yield classification in a soybean-rice rotation. Precis. Agric. 2010, 11, 507–519.

14. Shayan, M.; Fung, C.; Yoon, C.J.M.; Beschastnikh, I. Biscotti: A Blockchain System for Private and Secure Federated Learning. IEEE Trans. Parallel Distrib. Syst. 2020, 32, 1513–1525.

15. Yuan, Y.; Wang, F.Y. Towards blockchain-based intelligent transportation systems. In Proceedings of the 2016 IEEE 19th International Conference on Intelligent Transportation Systems (ITSC), Rio de Janeiro, Brazil, 1–4 November 2016; pp. 2663–2668.

16. Yu, K.; Tan, L.; Aloqaily, M.; Yang, H.; Jararweh, Y. Blockchain-enhanced data sharing with traceable and direct revocation in IIoT. IEEE Trans. Ind. Inform. 2021, 17, 7669–7678.

17. Yue, X.; Wang, H.; Jin, D.; Li, M.; Jiang, W. Healthcare data gateways: Found healthcare intelligence on blockchain with novel privacy risk control. J. Med. Syst. 2016, 40, 1–8.

18. Huang, C.; Wang, Z.; Chen, H.; Hu, Q.; Zhang, Q.; Wang, W.; Guan, X. RepChain: A Reputation-Based Secure, Fast, and High Incentive Blockchain System via Sharding. IEEE Internet Things J. 2021, 8, 4291–4304.

19. Qiao, Y.; Lan, Q.; Zhou, Z.; Ma, C. Privacy-preserving credit evaluation system based on blockchain. Expert Syst. Appl. 2022, 188, 115989.

20. Giraldo, F.D.; Gamboa, C.E. Electronic Voting Using Blockchain and Smart Contracts: Proof of Concept. IEEE Lat. Am. Trans. 2020, 18, 1743–1751.

21. Zhang, E.; Li, M.; Yiu, S.M.; Du, J.; Zhu, J.Z.; Jin, G.G. Fair hierarchical secret sharing scheme based on smart contract. Inf. Sci. 2021, 546, 166–176.

22. Katsikouli, P.; Wilde, A.S.; Dragoni, N.; Høgh-Jensen, H. On the benefits and challenges of blockchains for managing food supply chains. J. Sci. Food Agric. 2020, 101, 2175–2181.

23. Yin, B.; Yin, H.; Wu, Y.; Jiang, Z. FDC: A secure federated deep learning mechanism for data collaborations in the Internet of Things. IEEE Internet Things J. 2020, 7, 6348–6359.

24. Zhang, Q.; Han, Y.Y.; Su, Z.B.; Fang, J.L.; Liu, Z.Q.; Wang, K.Y. A storage architecture for high-throughput crop breeding data based on improved blockchain technology. Comput. Electron. Agric. 2020, 173, 105395.

25. Nurgazina, J.; Pakdeetrakulwong, U.; Moser, T.; Reiner, G. Distributed ledger technology applications in food supply chains: A review of challenges and future research directions. Sustainability 2021, 13, 4206.

26. Kamble, S.S.; Gunasekaran, A.; Gawankar, S.A. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. Int. J. Prod. Econ. 2020, 219, 179–194.

27. Benyam, A.A.; Soma, T.; Fraser, E. Digital agricultural technologies for food loss and waste prevention and reduction: Global trends, adoption opportunities and barriers. J. Clean. Prod. 2021, 323, 129099.

28. Khan, P.W.; Byun, Y.C.; Park, N. IoT-blockchain enabled optimized provenance system for food industry 4.0 using advanced deep learning. Sensors 2020, 20, 2990.

29. Zhang, X.; Sun, P.; Xu, J.; Wang, X.; Dong, Y. Blockchain-based safety management system for the grain supply chain. IEEE Access 2020, 8, 36398–36410.

30. Yadav, V.S.; Singh, A.R.; Raut, R.D.; Govindarajan, U.H. Blockchain technology adoption barriers in the Indian agricultural supply chain: An integrated approach. Resour. Conserv. Recycl. 2020, 161, 104877.

31. Leng, K.; Bi, Y.; Jing, L.; Fu, H.C.; Van Nieuwenhuyse, I. Research on agricultural supply chain system with double chain architecture based on blockchain technology. Future Gener. Comput.

Syst. 2018, 86, 641–649.

32. Ali, M.H.; Chung, L.; Kumar, A.; Zailani, S.; Tan, K.H. A sustainable Blockchain framework for the halal food supply chain: Lessons from Malaysia. Technol. Forecast. Soc. Chang. 2021, 170, 120870.

33. Song, L.; Wang, X.; Wei, P.; Lu, Z.; Wang, X.; Merveille, N. Blockchain-based flexible double-chain architecture and performance optimization for better sustainability in agriculture. CMC-Comput. Mater. Contin. 2021, 68, 1429–1446.

34. Ren, W.; Wan, X.; Gan, P. A double-blockchain solution for agricultural sampled data security in Internet of Things network. Future Gener. Comput. Syst. 2021, 117, 453–461.

35. Zeng, H.; Dhiman, G.; Sharma, A.; Sharma, A.; Tselykh, A. An IoT and Blockchain-based approach for the smart water management system in agriculture. Expert Syst. 2021, e12892.

36. Vangala, A.; Sutrala, A.K.; Das, A.K.; Jo, M. Smart contract-based blockchain-envisioned authentication scheme for smart farming. IEEE Internet Things J. 2021, 8, 10792–10806.

37. Durga, R.; Poovammal, E.; Ramana, K.; Jhaveri, R.H.; Singh, S.; Yoon, B. CES Blocks—A Novel Chaotic Encryption Schemes-Based Blockchain System for an IoT Environment. IEEE Access 2022, 10, 11354–11371.

38. Xu, D.; Gao, Y.; Xiao, X. Precision Poverty Alleviation Methods in the Agricultural Field Based upon Wireless Communication Networks and Blockchain. Wirel. Commun. Mob. Comput. 2022, 2022, 2687445.

39. Hu, S.; Huang, S.; Huang, J.; Su, J. Blockchain and edge computing technology enabling organic agricultural supply chain: A framework solution to trust crisis. Comput. Ind. Eng. 2021, 153, 107079.

40. Wang, J.; Zhang, X.; Xu, J.; Wang, X.; Li, H.; Zhao, Z.; Kong, J. Blockchain-Based Information Supervision Model for Rice Supply Chains. Comput. Intell. Neurosci. 2022, 2022, 2914571.