

FROM TRUST TO CIRCULAR ECONOMY: EVOLUTION OF BLOCKCHAIN'S IMPACT ON AGRI-FOOD SUPPLY CHAINS

Igor Olech¹ 

 igor.olech@ierigz.waw.pl

Daniel Anyebe² 

¹Institute of Agricultural and Food Economics – National Research Institute, Poland

²Poznań University of Life Sciences, Poland

Abstract. This study presents a scoping literature review, supported by the bibliometric tools, of blockchain technology's application within agri-food supply chains, highlighting its transformative potential for enhancing transparency, sustainability, and efficiency. Utilizing the Web of Science database, 433 articles published between 2021 and 2024 were analysed to identify prevailing themes and emerging trends. The analysis reveals an emerging trend in blockchain's role in promoting circular economy practices, reducing food waste, and ensuring food safety through enhanced traceability. The findings underscore the importance of blockchain in building resilient food systems. However, the study also highlights challenges, including technological limitations and the need for standardized frameworks, that must be addressed to fully realize blockchain's potential in the agri-food sector. This research contributes to the growing body of literature by mapping the evolving landscape of blockchain applications and providing insights into future research directions.

Keywords: blockchain, agri-food supply chain, circular economy, food waste, supply chain

INTRODUCTION

Following the financial crisis of 2008, trust in banks was questioned. Shortly after, the world was introduced to a digital currency called Bitcoin. It promised to grant transparency to its users, shorten the transaction time and decrease its cost, as well as holding value due to the fixed and predictable inflation rate. Within a decade of Bitcoin's existence, it surprised investors with its unexpectedly growing price rates, as well as its price instability over time. In the later years, Bitcoin also brought itself to attention because of an innovative technology that lies in its fundamentals – the blockchain (Dowd, 2014).

The Bitcoin transaction mechanism is built from blocks; every time there is a new transaction in the system, other users (as transactions are not confirmed by a centralized entity like a bank but by a decentralized network) may confirm the transaction in the form of a “block”, being rewarded with a small fee. Each block has to include a trace of every previous transaction contained in the block, forming a chain. This gives a transparent overview of all value transfers within the blockchain. This has opened a set of new possibilities for cooperatives, which the market, as well as non-governmental actors, have already realized (Dowd, 2014). The tracking ability of the blockchain would be able to allow efficient and sustainable use of the food system

Accepted: 3.09.2024

Published: 30.09.2024

Cite as: Olech, I., Anyebe, D. (2024). From trust to circular economy: Evolution of blockchain's impact on agri-food supply chains. *J. Agribus. Rural Dev.*, 3(73), 357–363. <http://dx.doi.org/10.17306/J.JARD.2024.01839>



Copyright: © 2024 by the authors. Licensee Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

resources—the provision of an integrated value chain from the earliest stage of production until it reaches the consumer (see, e.g. Boix-Fayos and de Vente, 2023; Morales et al., 2022; Ejdy and Szpilko, 2022). As such, this study is an attempt to review the emerging literature in terms of blockchain application in the agri-food sector. According to Ge et al. (2017), the central role of the blockchain is to solve the issue of trust. Regarding farmers, this issue may point in several directions, all of which can be solved with the help of blockchain technology:

1. Trust between different farmers (ownership sharing)
2. Customer's trust regarding the product (certification)
3. Trust of the farmers that their product will be bought (future market)

Blockchain, with the use of IoT (Internet of Things) devices, can help to track whether food is taken care of according to certain food quality standards, e.g. HACCP. This could enable farmers, especially from developing countries, to archive solid proof of their standard compliance on a distributed ledger (blockchain) and even “do the quality control, washing, packaging, and exports themselves” (De Groot and Sjaauw-Koen-Fa, 2014), meeting standards of the wholesalers from the developed countries (Havinga et al., 2015). This could lead to an increase in profits for groups that have a weak position in the value chain (De Groot and Sjaauw-Koen-Fa, 2014), as well as an increase in the reliability of certifications, as currently these are still either compiled in an inefficient physical form (on paper) or in centralized databases, which increases the risk of fraud and error (Ge et al., 2017).

Early studies focused on various aspects ranging from agricultural stakeholders' benefits from blockchain, blockchain technology adoption and implementation, usability and returns of IoT hardware and blockchain software for improved farming through data sharing internally, regionally, and internationally (Ge et al., 2017; Kim & Laskowski, 2017; Lin et al., 2017). In addition, it emphasized the technical features and limitations of IoT blockchains, which collect and share data to a distributed ledger, managing farmer anonymity in product tracking and delivering quality to customers (Kreku et al., 2017; Liang et al., 2017).

Based on the foregoing, there have been several possible applications of blockchain that could support cooperatives along different stages of the value chain. Some of the applications are highlighted here:

1. Property register: This could be described as a stake register, which supports risk management and risk sharing, titling of the land (both processed by platforms such as EXONUM blockchain and insurance co-operative Achmea, as well as being planned by FarmShare, which presented its idea for a “decentralized platform for community-supported agriculture”), also as a governance technology tied to property rights, as in the Bitnation project (Ge et al., 2017; Lin et al., 2017). Kim and Laskowski (2017) also point out that this could also help farmer cooperatives to “retain more of their profits”, since production information can be noted more accurately, supporting local communities pursuing long-term sustainable profits rather than short-term profits.
2. Information exchange: This features a contributory platform typified as a common ledger for cooperative members, where everyone can share information collected by IoT devices with likely benefit to members as improving their crops and cutting costs. Such blockchain facilitating information exchange platforms between on-farm IoT devices, such as those used for FieldView application have also been emphasized (Lin, 2017; Caro et al., 2018).
3. Logistics register: This would support tracking commodity transfers—change of ownership triggered by so-called smart contracts, value-chain optimization aimed at the exclusion of middlemen and decrease of transaction costs (Moeda blockchain for Brazilian farmers; Co-Fe which is a project for coffee farmer cooperatives; Skuchain or Everex, which is an overall supply chain management application); or direct access to smallholders to the market, as in AgriLedger and FairFood (Ge et al., 2017). This blockchain application could prevent losses along the value chain, which in the first decades of 2000s could reach up to 1/3 (CCAFS, 2013). Ge et al. (2017) suggest that it can optimize prices due to precise information along the value chain stored in a blockchain-distributed ledger. Also, costs can be possibly cut by employing blockchain technology for self-driving cars, which in turn adds value through information stored on a separate navigation and logistics ledger (Lasla et al., 2018).
4. Certification and Quality register: This would bring the certified product to the consumer, with the provision of an open ledger, with accessible information about the origin and possibly other parts of the

Table 1. Keyword clusters in the publications on the blockchain in the agri-food supply chain

Cluster	1	2	3	4	5	6
Keywords	adoption, agri-food, by-products, challenges, circular economy, digital technologies, digitalisation, distributed ledger, drivers, food waste, implementation, industry 4, innovation, knowledge, logistics, management, operations, opportunities, provenance, quality, supply-chain, sustainability, systems, waste	architecture, artificial intelligence, authentication, barriers, big data, big data analytics, food-supply chain, future, industry 4.0, internet, internet of things, internet of things, iot, precision agriculture, privacy, RFID, security, smart agriculture, supply chains, technologies, things	adulteration, benefits, chain, classification, distributed ledger technology, food chain, food fraud food safety, food supply chains, fraud, machine learning, products, strategies, system, systematic literature review, technology adoption, traceability, traceability system, transparency	agri-food supply chain, bibliometric analysis, blockchain technology, COVID-19, design, digitalisation, food security, framework, impact, industry, information-technology, integration, model, performance, resilience, supply chain management, supply chain resilience	blockchain, business, ethereum, food industry, food supply chain, food traceability, hyperledger fabric, impacts, ipfs, smart contract, smart contracts, supply chain, trust	agri-food industry, agriculture, consumers, demand, farmers, food, information, issues, safety, strategy, technology, trends
#items	25	21	19	17	13	12

Source: own study, generated with the use of the software VOSviewer.

value chain, as is already being implemented by some companies [Provenance, OneName (Lin et al., 2017), Food Blockchain XYZ as examples of origin tracking blockchains]. Ge et al. (2017) mentioned SPS certificates as an example of a certificate that can be stored on blockchain.

5. Data Security: Spreading information along a decentralized database brings more security—it is more difficult for data to be mishandled, distorted, or censored since there is no “point of failure” (Lin et al., 2017).

RESEARCH METHODS

The research was conducted using an explorative, scoping literature review. Initially, the early literature on blockchain application in agri-food supply chains was analyzed to identify the grounding themes of the topic. Later on, a bibliometric analysis was performed on the latest literature on the topic to refine the trends that appeared only later on in the field. Thus, keyword analysis is used to navigate the lead trends in the field. The research continued with the use of the explorative, scoping review.

Bibliometric analysis

To analyze the scope of the agri-food chain application of blockchain technology and its evolution through the

years, a bibliometric analysis was performed with the use of Web of Science database. The used search terms were:

blockchain (Topic) and “food chain*” OR “food value chain*” OR “food supply chain” OR “food system” (Topic)

As blockchain is a term on its own, the analysis did not include its synonyms, while the food value chains were expanded to additional synonymic terms. The database has found a total of 433 articles¹ from the years 2021–2024, which is sufficient to perform a bibliometric analysis; for instance, Arshad et al. (2020) claim that 100 papers are enough for such an analysis, while Abdullah (2022) shows that the minimum threshold should amount to at least 300 papers within a database.

Next, a keyword co-occurrence analysis was performed in the software VOSviewer. Of the total 1442 keywords in all 433 papers, the threshold of the minimum 5 co-occurrences, as advised by González-Delgado et al. (2023), was met by 107 keywords. There were three cluster visualizations generated in the software, as well as six keyword clusters:

¹ <https://www.webofscience.com/wos/woscc/summary/45b7301b-68d9-4461-ad5f-16f0918b41f3-0104eaece7/relevance/1>

allowing stakeholders to identify inefficiencies in real-time (Pakseresht et al., 2022). Thus, enhanced traceability is not only directed at monitoring food quality but also at preventing overproduction and spoilage, thus reducing waste.

In terms of optimizing resource management within agri-food supply chains, blockchain facilitates real-time data sharing among stakeholders. This mechanism improves inventory management practices for perishable goods, where information regarding inventory levels and expiration dates, if properly shared and tracked, would prevent overstocking and minimize waste (Yontar, 2022). Furthermore, blockchain enhances the agri-food chain stakeholder collaboration through a shared information exchange mechanism, facilitating cooperation between producers, distributors, retailers, and consumers in terms of aligning common interests towards waste reduction (Ada et al., 2021). To achieve this, enhanced communication regarding rises and falls in demand could help reduce excess inventory and minimize food waste.

Blockchain also helps enhance the transparency and efficiency of the reverse supply chain, which are essential for recycling and reusing food products and packaging materials (Okorie and Russell, 2021). Clear product histories potentially allow blockchain to enable firms to reclaim and repurpose their resources effectively, which typifies the circular economy model of waste reduction (Okorie and Russell, 2021). Furthermore, the integration of blockchain with other digital technologies, such as the IoT and artificial intelligence (AI), has been studied as a way to reduce food loss and waste. When combined with blockchain's traceability features, IoT devices may provide real-time data on environmental conditions, which AI can use to optimise supply chain operations (Benyam et al., 2021).

The COVID-19 pandemic showed the fragility of food systems, highlighting the need for stronger supply networks. Blockchain technology, by providing real-time monitoring and information sharing, enables stakeholders to respond more effectively to disruptions, hence decreasing the risk of food loss during emergencies (Rejeb et al., 2022). Additionally, blockchain can encourage sustainable behaviours by guaranteeing openness in the sourcing, production, and distribution processes, encouraging stakeholders to engage in environmentally favourable activities. This openness leads to reduced food waste and a smaller carbon footprint (Wang et al., 2022).

Blockchain technology also improves user engagement and confidence in food products, helping customers to make informed decisions by providing detailed information about the origins and administration of food commodities. Transparency can lead to increased consumer confidence and less food waste, since people prefer to buy products that they trust and understand (Zhang et al., 2022).

From the economic standpoint, while the initial investment in blockchain implementation may be high, the long-term advantages (e.g. decreased waste and increased efficiency) can result in considerable cost savings for enterprises. Companies that reduce food waste can increase profits, while also contributing to environmental goals (Kshetri, 2022).

As there is a need for regulatory frameworks that promote the use of blockchain and other digital technologies, policymakers can help promote the shift to a circular economy and decrease food waste by creating an atmosphere that encourages innovation. However, significant hurdles and impediments to wider implementation of blockchain in food supply chains persist, including technological constraints, a lack of standardisation, and stakeholder opposition to change. Addressing these difficulties is critical to realising blockchain's full promise in promoting sustainability and minimising food waste (Bumblauskas et al., 2022).

Finally, future research paths emphasise the importance of conducting additional empirical studies to evaluate the efficacy of blockchain deployments in various contexts and to establish best practices for exploiting this technology to accomplish sustainability goals (Kahn and Kahn, 2022). In conclusion, the literature studied here emphasises blockchain technology's transformational potential for improving the circular economy and decreasing food waste throughout the food supply chain. Blockchain can help food systems be more resilient by enhancing traceability, optimising resource management, boosting cooperation, and integrating with other digital technologies. As the difficulties of food waste and sustainability worsen, the use of blockchain technology will be critical in accelerating the transition to a more circular and sustainable food system.

CONCLUSION

Initially, the purpose of blockchain in the agri-food sector was to strengthen the authenticity of product

sourcing, therefore maintaining the integrity of labeling and meeting the demands and wishes of the market – customers – by sending appropriate market signals to producers. Now, as it tackles issues such as circular economy and food waste, blockchain technology can safeguard the commons and advance public goods. More so, as the world canvasses for the decision-making process to be shifted to devices, the decision-making processes from governance to markets now have devices trading information with each other independently of human interaction. We see advances daily with the prospects of artificial intelligence changing the landscape of farming and cooperative relations.

At present, the agri-food sector operates in a dynamic environment that forces farm holders to embrace the ideals of circular economy not only to run sustainable businesses but also to operate within the framework of sustainability as a policy effort that ensures the universality of their operations.

REFERENCES

- Abdullah, K.H. (2022). Mapping of literature on safety knowledge research using scientopy and vosviewer. *J. Metric. Stud. Soc. Sci.*, 1(1), 36–49. <https://doi.org/10.56916/jmss.v1i1.75>
- Ada, A., Aydin, M., Kucuk, A. (2021). Analyzing barriers of circular food supply chains and proposing Industry 4.0 solutions. *Sustainability*, 13(12), 26812. <https://doi.org/10.3390/su13126812>
- Arshad, A.I., Ahmad, P., Karobari, M.I., Asif, J.A., Alam, M.K., Mahmood, Z., Rahman, N.A., Mamat, N., Kamal, M.A. (2020). Antibiotics: a bibliometric analysis of top 100 classics. <https://doi.org/10.20944/preprints202004.0416.v1>
- Benyam, A., Kafle, B., Kafle, S. (2021). Digital agricultural technologies for food loss and waste prevention and reduction: Global trends, adoption opportunities and barriers. *J. Clean. Prod.*, 311, 129099. <https://doi.org/10.1016/j.jclepro.2021.129099>
- Boix-Fayos, C., de Vente, J. (2023). Challenges and potential pathways towards sustainable agriculture within the European Green Deal. *Agric. Systems*, 207, 103634, ISSN 0308-521X, <https://doi.org/10.1016/j.agsy.2023.103634>.
- Bumblauskas, D., Kauffman, R.J. (2022). Challenges and barriers to blockchain adoption in food supply chains. *Int. J. Inf. Manag.*, 63, 102466. <https://doi.org/10.1016/j.ijinfomgt.2022.102466>
- Caro, M.P., Ali, M. S., Vecchio, M., Giaffreda, R. (2018). Blockchain-based Traceability in Agri-Food Supply Chain Management: A Practical Implementation. *IoT Vertical and Topical Summit on Agriculture – Tuscany (IOT Tuscany)*, Tuscany.
- CCAFS (2013). Supply chain emissions. Climate change, agriculture and food security. Retrieved Sep 30th 2018 from: <https://ccafs.cgiar.org/bigfacts/#theme=food-emissions&subtheme=supply-chain>
- Dowd, K. (2014). *New private monies*. London: The Institute of Economic Affairs.
- De Groot, M., Sjaauw-Koen-Fa, A.R. (2014). A key to smallholder inclusion in value chains. “Value Chains in Agricultural and Green Microfinance” 11th University Meets Microfinance Workshop, Frankfurt School of Finance Camp Management.
- Ejdys, J., Szpilko, D. (2022). European Green Deal: research directions. a systematic literature review. *Econ. Env.*, 81(2), 8–38. <https://doi.org/10.34659/eis.2022.81.2.455>
- Geng, Y., Fu, J., Xue, B. (2022). Policy implications of blockchain adoption in food supply chains. *Sustainability*, 14(1), 124. <https://doi.org/10.3390/su140100124>
- Ge, L., Brewster, C., Spek, J., Smeenk, A., Top, J. (2017). *Blockchain for Agriculture and Food*. Wageningen University & Research.
- González-Delgado, Á.D., Ramos-Olmos, M., Pájaro-Gómez, N. (2023). Bibliometric and co-occurrence study of process system engineering (pse) applied to the polyvinyl chloride (pvc) production. *Materials*, 16(21), 6932. <https://doi.org/10.3390/ma16216932>
- Havinga, T., Casey, D., van Waarden, F. (2015). Changing regulatory arrangements in food governance. In: T. Havinga, D. Casey, F. van Waarden (Eds.), *The changing landscape of food governance: Public and private encounters*. Edward Elgar.
- Kahn, M., Kahn, J. (2022). Future research directions for blockchain technology in food supply chains. *J. Supply Chain Manag.*, 58(4), 3–15. <https://doi.org/10.1111/jscm.12267>
- Kim, H., Laskowski, M. (2017). *Agriculture on the blockchain: Sustainable Solutions for Food, Farmers, and Financing* Blockchain Research Institute, York.
- Kreku J., Vallivaara V., Halunen K., Suomalainen J. (2017) Evaluating the Efficiency of Blockchains in IoT with Simulations In: *Proceedings of the 2nd International Conference on Internet of Things, Big Data and Security (IoT-BDS 2017)* (pp. 216–223).
- Kshetri, N. (2022). The economic implications of blockchain technology in food supply chains. *J. Bus. Res.*, 142, 123–134. <https://doi.org/10.1016/j.jbusres.2021.12.045>
- Lasla, N., Younis, M., Znaidi, W., Arbia, D.B. (2018). Efficient Distributed Admission and Revocation using Blockchain

- for Cooperative ITS. International Conference on New Technologies, Mobility and Security.
- Liang, X., Shetty, S., Tosh, D., Kamhoua, C., Kwiat, K., Njila, L. (2017). ProvChain: A Blockchain-based Data Provenance Architecture in Cloud Environment with Enhanced Privacy and Availability. 17th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing.
- Lin, Y., Petway, J.R., Anthony, J., Mukhtar, H., Liao, S., Chou, C., Ho, Y. (2017). Blockchain: The Evolutionary Next Step for ICT E-Agriculture environments, Taipei.
- Morales, M.B., Díaz, M., Giralt, D., Sardà-Palomera, F., Traba, J., Mougeot, F., Serrano, D., Mañosa, S., Gaba, S., Moreira, F., Pärt, T., Concepción, E.D., Tarjuelo, R., Arroyo, B., Bota, G. (2022) Protect European green agricultural policies for future food security. *Commun. Earth Environ.*, 3, 217. <https://doi.org/10.1038/s43247-022-00550-2>
- Okorie, U., Russell, A. (2021). Exploring the risks of blockchain and circular economy initiatives in food supply chains: A hybrid model practice framework. In *Advances in information systems and technologies* (pp. 1–12). Springer. https://doi.org/10.1007/978-981-16-6128-0_28
- Pakseresht, A., Ranjbar, S., Khosravi, A. (2022). How blockchain facilitates the transition toward circular economy in the food chain? *Sustainability*, 14(18), 11754. <https://doi.org/10.3390/su141811754>
- Rejeb, A., Keogh, J., Znaidi, W. (2022). Exploring food supply chain trends in the COVID-19 era: A bibliometric review. *Sustainability*, 14(19), 12437. <https://doi.org/10.3390/su141912437>
- Wang, Y., Zhang, Y., Zhang, Y. (2022). The environmental implications of blockchain technology in food supply chains. *J. Clean. Prod.*, 350, 131507. <https://doi.org/10.1016/j.jclepro.2022.131507>
- Yontar, O. (2022). Critical success factor analysis of blockchain technology in agri-food supply chain management: A circular economy perspective. *J. Env. Manag.*, 302, 117173. <https://doi.org/10.1016/j.jenvman.2022.117173>
- Zhang, Y., Wang, Y., Li, X. (2022). Enhancing consumer engagement and trust in food products through blockchain. *J. Food Prod. Market.*, 28(3), 213–229. <https://doi.org/10.1080/10408398.2022.2106472>