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Blockchain's Impact on Coffee Supply Chains: A Systematic Literature Review

Rina[1*], Mulia Rahmayu[2], Taopik Hidayat[3]

[1,] Sistem Informasi, Universitas Nusa Mandiri, Jakarta
[2,] Teknologi Informasi, Universitas Bina Sarana Informatika, Jakarta
[3,] Sains Data, Universitas Nusa Mandiri, Jakarta

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ABSTRACT

Coffee is a globally significant commodity with high economic value and extensive social impact. Nevertheless, the intricate nature of the coffee supply chain frequently leads to issues concerning visibility, traceability, and sustainability. Blockchain offers a decentralized, transparent, and secure approach to mitigate these problems effectively. This research seeks to explore the current trends, core motivations, and auxiliary technologies that facilitate the integration of blockchain technology within the coffee supply chain. A total of 16 scientific articles published in Scopus-indexed journals (Q1 to Q4) between 2019 and 2024 were selected and analyzed using the Systematic Literature Review (SLR) method. The findings reveal that traceability and transparency are the primary focuses of blockchain implementation. The study also identifies several supporting technologies, such as smart contracts, Distributed Ledger Technology, IoT, NFT, and Artificial Intelligence, which play critical roles in enhancing the efficiency and security of blockchain-based coffee supply chains.

Corresponding Author:

Rina,
Sistem Informasi,
Universitas Nusa mandiri,
Jakarta, Indonesia,
Email: 11200244@nusamandiri.ac.id

INTRODUCTION

More than two billion cups of coffee are brewed and enjoyed every day in various parts of the world. This high number makes coffee one of the most popular beverages globally, alongside mineral water and tea (Stefanello et al., 2019), (Yele & Litoriya, 2024). This phenomenon not only reflects global consumer preferences but also highlights coffee's position as one of the world's most heavily traded commodities and its substantial impact on the economic growth of numerous nations (Eron et al., 2024), (Infante et al., 2023). In Indonesia, coffee ranks third among the largest plantation commodities, following palm oil and rubber (Pusdatin, 2022).

According to data from the United States Department of Agriculture (USDA), global coffee production in the 2023/2024 season is estimated to reach 171.43 million bags, with each bag containing 60 kg of coffee. During the same period, Indonesia successfully produced 9.7 million bags of coffee, a decrease of 18% compared to the previous period ("Production - Coffee," 2024). Despite the decrease, Indonesia continues to hold the fourth position among the world's largest coffee producers, behind Brazil, Vietnam, and Colombia (Eron et al., 2024).

The coffee supply chain involves diverse stakeholders, including farmers and end-consumers (Freitas et al., 2024). This chain initiates with farmers who grow and harvest coffee beans, subsequently selling them to

collectors. These collectors procure coffee beans from multiple farmers and conduct sorting procedures to guarantee the quality of the beans, which are then transported to manufacturers for additional processing. At the manufacturing stage, coffee beans undergo several processes and are ultimately distributed to consumers via coffee shops, supermarkets, or retail outlets (Alamsyah et al., 2023).

The complexity of the supply chain often presents various challenges, such as transparency issues (Vegro & de Almeida, 2020), price fluctuations, difficulties in tracing the origin of coffee, and sustainability concerns (Alamsyah et al., 2023). These challenges can affect product quality and lead to consumer distrust regarding the authenticity of the products they purchase(Ravi et al., 2022). Address these issues, a comprehensive and innovative approach is needed to ensure traceability, maintain price stability, and implement sustainable practices throughout all stages of the supply chain (Tharatipyakul et al., 2022).

Blockchain serves as a technology designed for decentralized data storage and management (Tripathi et al., 2023). This technology allows for the distribution of data across various nodes or connected computers in a network without requiring oversight from a central authority (Trollman et al., 2022). Each node in the network maintains an identical copy of the data, enabling all members of the network to view and trace every transaction and activity occurring within the system (Abebe & Semegn, 2021). In addition to its decentralized nature, blockchain relies on complex cryptographic mechanisms to ensure that the stored data remains secure and cannot be altered or manipulated without authorization (Shyamala Devi et al., 2019).

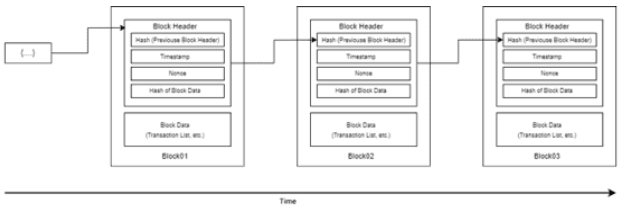

Figure 1. Blockchain Structure

In 2008, blockchain technology was initially introduced by a pseudonymous entity or group under the name Satoshi Nakamoto through the creation of Bitcoin, a cryptocurrency (Nerurkar et al., 2021) with the blockchain structure illustrated in Figure 1. Although they are frequently associated, Bitcoin and blockchain are distinct concepts. Bitcoin represents the first application that utilizes blockchain to enable peer-to-peer (P2P) transactions without the involvement of an intermediary (Kasi et al., 2022). In contrast, blockchain is the underlying technology of Bitcoin, serving as a secure and distributed digital ledger (Mokalusi et al., 2022).

One important aspect of blockchain technology is the use of smart contracts. Smart contracts are digital contracts designed to automatically execute and enforce specific conditions without requiring human intervention (Bassan & Rabitti, 2024). While initially used for simple agreements, the development of blockchain technologies such as Bitcoin and Ethereum has enabled their application in more complex transactions (Stazi, 2021). Blockchain technology possesses considerable potential to tackle multiple challenges within the coffee supply chain. It can improve transparency throughout all phases of the supply chain, verify the authenticity and traceability of information related to the origin and pathway of coffee, and ensure the security of transactions (Alamsyah et al., 2023).

To further explore how blockchain can address these challenges, this study will conduct an extensive literature review to assess the potential of blockchain technology in improving transparency, traceability, transaction security, and supporting sustainable practices within the coffee supply chain.

RESEARCH METHOD

This study adopts the Systematic Literature Review (SLR) method to systematically and comprehensively examine the scientific literature literature about the application of blockchain technology in the coffee supply chain. The SLR method was chosen because it allows for the identification, collection, analysis, and synthesis of evidence from previous research in a structured and directed manner to address the formulated research questions (Saxena et al., 2023). Compared to traditional literature reviews, the SLR method emphasizes a well-structured and well-documented process to minimize bias and enhance the reliability of the findings.

Figure 2. Stages of the Systematic Literature Review

Based on Figure 2, the SLR process comprises three primary stages: planning, conducting, and reporting. The planning stage focuses on formulating research questions, determining inclusion and exclusion criteria, and planning the literature search strategy. The conducting stage includes searching for literature, selecting studies based on criteria, extracting relevant data, and analyzing the data to answer the research questions. Finally, the reporting stage emphasizes the systematic and comprehensive presentation, interpretation, and discussion of the research findings (Carrera-rivera et al., 2022).

1. Research Questions

Research questions are formulated specifically to ensure the focus of the study and to guide the process of identifying, analyzing, and synthesizing relevant literature. The research questions summarized in Table 1 will be addressed in this study:

Table 1. List of Literature Review Research Questions

ID	Research Questions
RQ1	What are the trends in research related to the implementation of blockchain technology in the coffee supply chain over time?
RQ2	What are the main motivations for implementing blockchain technology in the coffee supply chain?
RQ3	What technologies are used to support the implementation of blockchain in the coffee supply chain?

2. Search Strategy

The search strategy was systematically designed to identify literature relevant to the implementation of blockchain technology in the coffee supply chain. Relevant literature was obtained from various sources using Harzing's Publish or Perish software, with the search keywords "Blockchain AND Coffee AND Supply Chain." This search focused on publications from 2019 to 2024 and identified a total of 45 relevant studies, as illustrated in Figure 3 below.

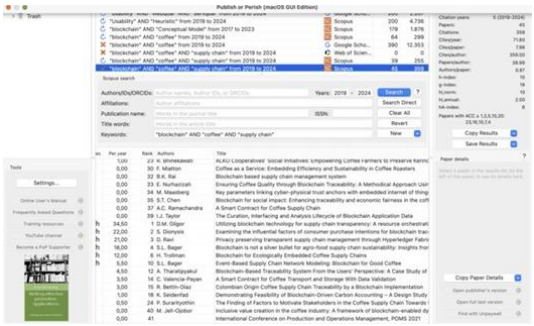

Figure 3. Literature Search Using Harzing's Publish or Perish Software

3. Study Selection

At this stage, the application of inclusion and exclusion criteria is used to ensure the validity and relevance of the literature to be analyzed (Prasetyo et al., 2024). These criteria encompass several aspects, such as the research topic, publication period, quality, and the language used in the scientific literature, as presented in Table 2.

Table 2. Inclusion and Exclusion Criteria

No	Inclusion Criteria	Exclusion Criteria
1	The study must discuss blockchain technology in the coffee supply chain.	The study does not address blockchain technology and its application in the coffee supply chain.
2	The study must be published within the period of 2019-2024.	The study is published before 2019 or after 2024.
3	The study must be accredited in Scopus Q1 to Q4.	The study is not accredited in Scopus or is a conference paper.
4	The study must be in English.	The study is in a language other than English.

After applying the established inclusion and exclusion criteria, the reduction process resulted in 16 scientific literature sources deemed most relevant for further analysis. The selected literature is considered to have high scientific quality and strong relevance to the topic under study, which is the application of blockchain technology in the coffee supply chain.

4. **Analysis & Reporting**
   The retrieved scientific literature will undergo systematic analysis to address the established research topics. This method seeks a more thorough comprehension of the potential, effects, and obstacles related to using blockchain technology within the coffee supply chain..

RESULTS AND DISCUSSION

RQ1: What are the trends in research related to the implementation of blockchain technology in the coffee supply chain over time?

The selected literature that has undergone the selection process is grouped by publication year. The primary goal of this grouping is to identify trends and developments in research on blockchain technology in the coffee supply chain. This chronological approach enables a comprehensive mapping of the evolution and advancements of blockchain technology in the sector. Additionally, grouping the literature by publication year is crucial for identifying research gaps that remain unanswered and discovering relevant and high-potential research opportunities.

Figure 4 presents the temporal distribution of scientific publications related to the implementation of blockchain technology in the coffee supply chain from 2019 to 2024. Based on the established inclusion and exclusion criteria, no relevant publications were found in 2019 and 2020. This phenomenon transitioned in 2021 with the emergence of two publications, followed by a significant increase in 2022, which saw a total of six publications. This trend slightly declined in 2023, with four publications. However, by mid-2024, an additional four publications were recorded. This trend indicates that research on blockchain in the coffee supply chain continues to evolve and is projected to increase further by the end of 2024.

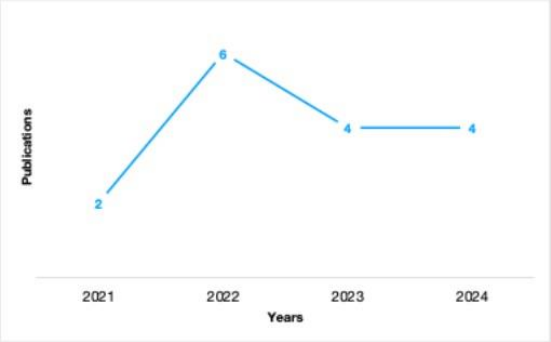

Figure 4. Publication Distribution by Year of Publication

In addition to temporal trends, the literature mapping is also conducted based on the ranking of the journals in which the publications appear. This provides insights into the quality and credibility of research related to blockchain in the coffee supply chain. Figure 5 shows that the majority of publications are indexed in Scopus Q1, totaling eight publications. This indicates that the topic of blockchain for coffee supply chain is regarded as important within the academic community and has reached a high level of maturity and quality. On the other hand, there are three publications in Q2 journals, four in Q3 journals, and one in a Q4 journal, the summaries of which can be found in Table 1. This distribution suggests that there is still room for improvement in research quality and the need for broader dissemination of research findings, particularly in high-reputation journals, to enhance the impact of the research.

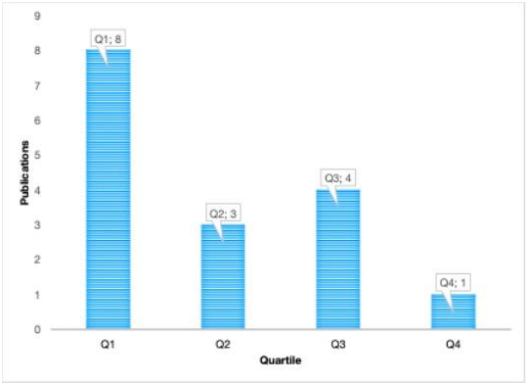

Figure 5. Distribution of Publications Based on Journal Ranking

RQ2: What are the main motivations for implementing blockchain technology in the coffee supply chain?

The literature mapping regarding the motivations or primary objectives for implementing blockchain technology in the coffee supply chain reveals a compelling and diverse research focus. Figure 6 shows that traceability is the main focus of various studies. This indicates a high interest among researchers to explore blockchain's potential in enhancing the traceability of the origins, journey, and security of coffee products. Transparency ranks as the second most important goal frequently explored in research. The improvement of information transparency at every stage of the supply chain, from farmers to end consumers, is expected to be achieved through the utilization of blockchain technology. Interestingly, several other goals such as sustainability, economics, food security, and decentralization also emerge in the literature review. These diverse goals indicate that research on blockchain technology in the coffee supply chain is not only focused on technical and logistical aspects but also considers its impact on sustainability, economic factors, and a more equitable food system.

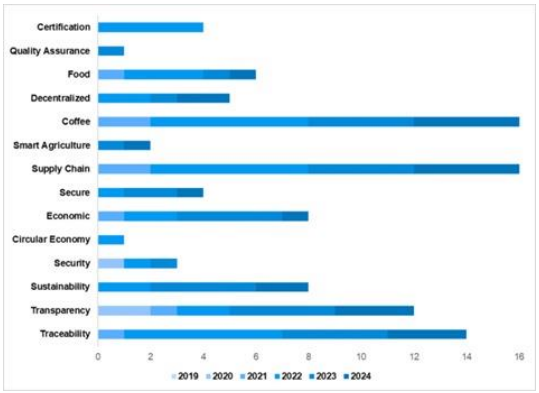

Figure 6. Distribution of Research Objectives for Blockchain Technology on Coffee Supply Chain

RQ3: What technologies are used to support the implementation of blockchain in the coffee supply chain?

Based on Figure 7, the literature mapping indicates various technologies that play a crucial role in supporting the implementation of blockchain in the coffee supply chain. These include smart contracts, Distributed Ledger Technology (DLT), Internet of Things (IoT), Non-Fungible Tokens (NFT), Artificial Intelligence (AI), and more. These technologies complement each other to create a more efficient, transparent, and secure supply chain system. Smart contracts enable the automation of business processes, while DLT ensures data security and transparency. IoT provides real-time data on growth conditions, harvests, and coffee shipments. NFTs facilitate product authenticity and help prevent counterfeiting, especially for certified premium coffee. Additionally, AI is utilized to analyze the vast amounts of data collected through IoT and blockchain systems, aiding in market demand prediction, supply chain optimization, and proactive problem identification. Thus, the integration of these technologies has the potential to drive positive transformation in the coffee industry, enhancing traceability and sustainability while empowering farmers and increasing consumer trust.

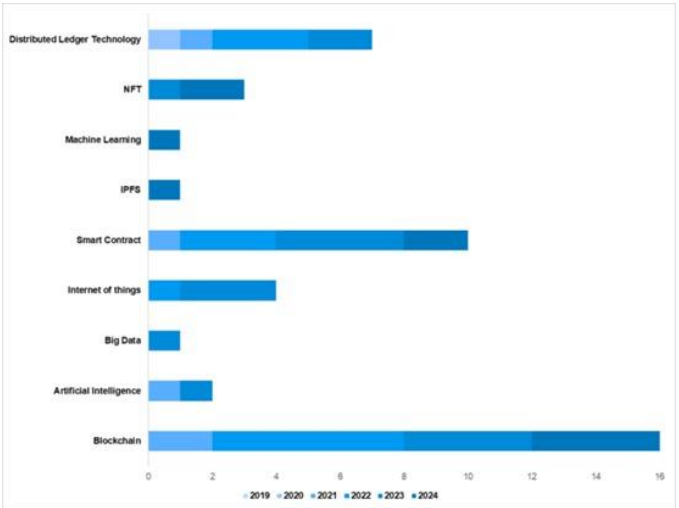

Figure 7. Distribution of Technologies Supporting Blockchain in Coffee Supply Chain

Table 3. Summary of Blockchain Research on the Coffee Supply Chain in Literature Review

Author	Objective	Results	Quartile
Abebe & Semegn, 2021	Enhance traceability and transparency in the Ethiopian coffee supply chain using blockchain.	Prototype traceability system for coffee using Hyperledger Fabric.	Q4
Kramer et al., 2021	Determine the issues affecting the implementation of blockchain-based technology inside the coffee supply chain.	Development of a stakeholder management-based blockchain adoption model.	Q3
Valencia-Payan et al., 2022	Develop smart contracts to monitor coffee using blockchain.	Smart contracts can effectively monitor coffee status in real time.	Q1
Tharatipyakul et al., 2022	Develop a blockchain-based traceability system to enhance coffee security and value.	User-friendly prototype traceability system that improves coffee security and value.	Q1
Bager et al., 2022	Develop a sustainable coffee supply chain system using blockchain technology.	Blockchain can improve efficiency and transparency, but challenges remain.	Q2
Bettín-Díaz et al., 2022	Test the feasibility of blockchain technology for coffee supply chain traceability systems.	Concept of a traceability system using Hyperledger Fabric shows blockchain's potential for improving product origin transparency.	Q3
(Ravi et al., 2022)	Improve the management of supply chains protocols with the integration of blockchain technology.	The Hyperledger Fabric blockchain platform enhances the security, privacy, transparency, and integrity of data throughout the coffee supply chain.	Q1
Gligor et al., 2022	Analyze the potential of blockchain to improve transparency in the coffee supply chain.	Blockchain enhances information transparency and adds value for stakeholders in the coffee industry.	Q1
Saputra et al., 2023	Develop dynamic smart contracts for agricultural supply chains like coffee and fish.	AniraBlock concept improves transparency and data integrity through adaptive and scalable dynamic smart contracts.	Q3
Alamsyah et al., 2023	Develop a blockchain-based model and application to enhance transparency and traceability in the coffee supply chain.	Prototype application to monitor coffee's journey from farmers to consumers, ensuring fair pricing and quality.	Q1
Gazzola et al., 2023	Analyze the potential of blockchain to enhance traceability and transparency in food supply chains.	Blockchain effectively traces product origins, boosts consumer trust, and strengthens collaboration among stakeholders within the Lavazza coffee supply chain.	Q1
Pradana et al., 2023	Develop a blockchain-based traceability system for Indonesian coffee.	The blockchain traceability prototype enhances confidence and transparency throughout the Indonesian coffee supply chain.	Q2
Saputra et al., 2024	Develop dynamic smart contracts to improve efficiency and transparency in agricultural supply chains.	Dynamic smart contracts proved to be faster, more resilient, and easier to manage, enhancing efficiency, transparency, and scalability.	Q3
Ligar et al., 2024	Develop a blockchain and machine learning-based traceability system to ensure coffee bean quality.	Traceability system using smart contracts and ML (YOLOv5m) effectively monitors the supply chain and verifies coffee bean quality.	Q2
Ordoñez et al., 2024	Create smart contracts to improve transparency and sustainability within Colombia's coffee supply chain.	SmartBeanFutures platform enhances transparency, trust, and greater control for farmers in the coffee supply chain.	Q1

Nudin et al., 2024	Analyze the readiness for implementing blockchain technology to trace the authenticity of organic coffee.	Blockchain implementation is influenced by ease of use, benefits, and positive consumer attitudes towards its use.	Q1

CONCLUSION

The paper seeks to identify and analyze trends in research, major motivations, and supporting technologies for applying blockchain technology within the supply chain for coffee. 16 scholarly articles published in Scopus Q1 to Q4 journals between 2019 and 2024 were selected and analyzed focusing on the specified inclusion and exclusion criteria for this research. The results demonstrate that blockchain technology possesses considerable potential for improving transparency, traceability, and sustainability on the coffee supply chain. Additional research is advised to corroborate these findings by broadening the literature review, formulating more tangible and pragmatic blockchain implementation frameworks, and performing empirical investigations in the domain to thoroughly assess their efficacy.

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