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LEVERAGING BLOCKCHAIN TECHNOLOGY FOR ENSURING THE INTEGRITY OF HALAL SUPPLY CHAINS: A SYSTEMATIC REVIEW

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Review paper

ABSTRACT

Over the past decade, the demand for halal-certified products and services has grown exponentially in various sectors such as food, cosmetics, pharmaceuticals and finance. Previous academic research has shown that traceability, transparency and certification compliance are the main drivers of halal purchasing behaviour. In practice, however, we have found that traceability, transport and storage, end-to-end chain integrity, different halal systems and lack of IT integration contribute to the disruption of halal supply chains. The characteristics of blockchain technology (i.e. decentralisation, immutability, transparency and cryptographic security) should, on paper, facilitate the tracking and verification of halal products from their origin to the end consumer.

In this paper, we explored the pivotal role of blockchain technology in improving the efficiency and reliability of halal supply chains.

The paper has been designed as a systematic literature review based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. The review of the relevant academic literature has been further integrated and enriched by other sources such as regulatory frameworks and case studies. In doing so, we aimed to provide an updated theoretical and practical view of the adoption of blockchain technology in the context of the halal supply chain.

Preliminary findings suggest that the use of blockchain-based solutions in halal supply chains would increase visibility, trust and accountability, and consequently foster greater trust among halal consumers. In terms of challenges, scalability issues, interoperability concerns and regulatory hurdles would undoubtedly pose significant hurdles for industry stakeholders.

Keywords: *halal supply chains, blockchain, PRISMA, systematic literature review.*

Introduction

The halal industry encompasses products and services that comply with Islamic law and are therefore defined as halal, which means permissible, as opposed to haram, which means forbidden. Historically, Muslims globally have adhered strictly to consuming only halal products, leading to the development of a thriving market across seven primary sectors: food and beverages, finance, clothing, tourism, media, pharmaceuticals, and cosmetics (Alamsyah *et al.*, 2022).

In 2021, the worldwide expenditure of Muslims across the various sectors amounted to a total of two trillion U.S. dollars, with the halal food and beverage sector representing the largest market for Muslim consumers. Projections indicate that

the global Muslim market could expand to approximately 2.8 trillion dollars by 2025 (Statista, 2024).

In order to assure Muslim consumers of the halal status of products and services, certification bodies play a critical role in verifying manufacturing processes from preparation to distribution. Ultimately, the halal certification logos provide consumers with indicators of compliance with halal guidelines and Shariah principles (Ab Talib *et al.*, 2015; Hew *et al.*, 2020).

Halal supply chains, however, encounter numerous obstacles, such as preserving halal integrity, guaranteeing transparency, and addressing consumer worries regarding trust and authenticity (Novianti *et al.*, 2020). Conventional supply chain difficulties like delayed delivery, mishandling, and contamination become more pronounced within halal supply chains. Moreover, the absence of standardized global halal regulations adds complexity to ensuring halal compliance and integrity (Tieman and Darun, 2017; Tieman *et al.*, 2019; Ali *et al.*, 2021).

In this regard, Blockchain technology is emerging as a potential solution to improve transparency, traceability and integrity in halal supply chains. By leveraging blockchain, halal supply chains can overcome challenges related to traceability, product integrity, transportation, and integration of information systems. The real-time visibility and transparency facilitated by blockchain can address the complexity of halal supply chains and ensure compliance with halal standards (Alamsyah *et al.*, 2022; Tan *et al.*, 2022).

The academic literature on the implementation of blockchain technology in halal food supply chains is still in its infancy, due to the relative novelty of this technological innovation. In accordance with relevant authors, we found that previous research on this topic is indeed quite fragmented, presenting purely theoretical discussions with a relative lack of empirical investigations (Ali *et al.*, 2021; Sultana *et al.*, 2022; Bux *et al.*, 2022). In our opinion, in order to fully understand the potential of blockchain in the context of halal food, it is necessary to present an overall view of the topic so that future research can then focus on a theoretical framework based on practical scenarios.

Therefore, with this work, we aim to provide an up-to-date perspective on the impact of blockchain technology on the halal food supply chain industry. The study is therefore designed as a systematic literature review based on the Prisma approach (Moher *et al.*, 2009) and answers the research question “Can blockchain technology enhance the reliability, traceability and sustainability of Halal foods?”.

The paper is structured as follows: in section 2 we present the theoretical framework to clarify the theoretical underpinnings of the phenomenon under analysis, in section 3 we present the methodology used, and in section 4 we present our results and discussion of the findings.

Theoretical background

Halal Supply Chains (HSCs) are characterized by the integration of Halal principles across all stages of manufacturing, sourcing, distribution, and logistics operations. The following Fig. 1 offers a possible conceptual model of Halal Supply Chain Management (Sulaiman *et al.*, 2018; Novianti *et al.*, 2020).

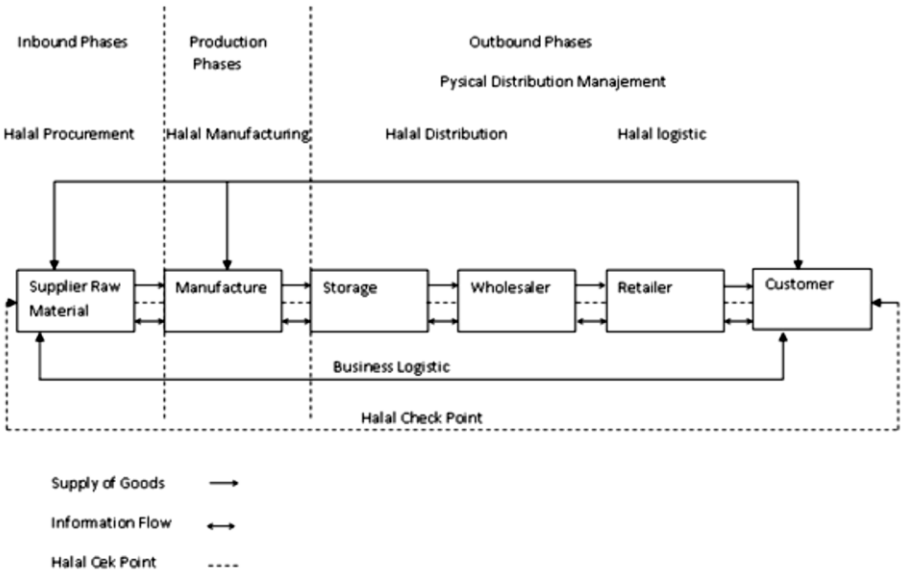

Figure 1. Conceptual Model of Halal Supply Chain Management. Source: Novianti et al. 2020, p. 160

More specifically, we can break down the overall halal production and distribution process into the following three main phases:

1. *Inbound phase (Halal Procurement):* Upon receipt of a Halal certificate, the supplier delivers raw materials for processing by a designated company.
2. *Production phase (Halal Manufacturing)*: These materials are converted into processed food products before being stored in a warehouse for subsequent distribution to wholesalers.
3. *Outbound Phases (Halal distribution /Logistics)*:
    i. After receiving offers and product requests, wholesalers distribute according to wholesale demand.
    ii. The processed products are then distributed to retailers, who market them directly to consumers.

Ideally, every participant in the HSC, including consumers, should be able to verify the halal status of food products through easily accessible checkpoints and transparent information systems across the entire supply chain (Rohmah *et al.*, 2019).

In practice, however, Halal SCs encounter various challenges, including traceability issues, compliance with Shariah requirements, and the lack of standardized certification systems (Surjandari *et al.*, 2021; Tieman *et al.*, 2019).

The key challenges typically encountered in conventional supply chains are exacerbated in Halal SCs, including issues such as cross-contamination, counterfeiting and logistical challenges. This highlights the need for standardised Halal regulations and improved traceability systems (Ali *et al.*, 2017; Tan *et al.*, 2017).

Current track and trace mechanisms used in the halal food industry, including RFID, barcodes and GPS devices, lack real-time visibility, multi-party information sharing and end-to-end transparency. These shortcomings highlight the need for unified, blockchain-enabled solutions that can securely capture and validate data across the supply chain in real time (Tan *et al.*, 2022).

Traditionally, supply chain data has been stored and redistributed through centralized storage architectures. In contrast, blockchain technology operates on distributed systems logic, presenting numerous advantages over centralized systems, such as improved traceability, crucial for identifying the provenance and halal compliance of food items within supply chains (Abeyratne and Monfared, 2016; Ali *et al.*, 2021). Moreover, blockchain technology promises to foster transparent and efficient communication among SC stakeholders and has the potential to promote trust, confidence, and economic growth in the Islamic economy (Chandra *et al.*, 2019).

The definition of "blockchain" continues to spark debate among scholars; some define blockchain as a "distributed data structure, database, or system" while others characterize it as a "decentralized network". For the purposes of this

discussion, we align with the definition suggested by Seebacher and Schüritz in their 2017 paper "Blockchain Technology as an Enabler of Service Systems: A Structured Literature Review":

A blockchain is a distributed database, which is shared among and agreed upon a peer-to-peer network. It consists of a linked sequence of blocks, holding timestamped transactions that are secured by public-key cryptography and verified by the network community. Once an element is appended to the blockchain, it cannot be altered, turning a blockchain into an immutable record of past activity (Seebacher and Schüritz, 2017, p. 3).

In particular, a blockchain offers a decentralised approach in which transactions between parties are securely and permanently recorded, facilitating the sharing of databases between multiple parties and eliminating the need for intermediaries who have traditionally verified, recorded and coordinated transactions. Centralised authorities are therefore rendered redundant, and blockchain forms a cornerstone of what has been described as a "trust machine" (Rohmah *et al.*, 2019).

Although blockchain technology was initially adopted primarily by the financial industry, it has now spread to various sectors and applications, including global container carriers, fraud detection systems for luxury goods, multinational retail companies and pharmaceutical distribution (Ziegler and Uli, 2021). It is also highlighted that the implementation of blockchain in various industries often requires complementary technologies, in particular the Internet of Things (IoT), especially in the food and logistics sectors, where the convergence of blockchain and IoT systems can promote transparency and consumer confidence in asset traceability (Alamsyah *et al.*, 2022). Blockchain technology also has the potential to offer unprecedented track-and-trace capabilities if the blockchain architecture also integrates smart contracts, namely digital contracts that are stored on the blockchain and automatically executed when certain conditions are met (Rohmah *et al.*, 2019). Vivaldini (2021) maintained that smart contracts play a pivotal role in automating quality control processes in supply chains, thereby minimizing error records (Vivaldini, 2021).

Agency theory supports the adoption of blockchain in the context of halal supply chain management since moving from a centralised to a decentralised system enhances traceability and data transparency, further strengthening the benefits of blockchain adoption (Ali *et al.*, 2021; Tan *et al.*, 2022; Novianti *et al.*, 2020). Surjandari *et al.* (2021) found that combining blockchain technology with halal certification can mitigate key challenges in halal supply chains, namely contamination and disobedience. Tan *et al.* (2022) highlighted that current track and trace solutions for halal supply chains based on traditional technologies (e.g. barcodes, RFID and GPS devices) lack real-time visibility, whereas blockchain technology could enable effective and efficient real-time data collection and secure access throughout the supply chain.

In conclusion, the adoption of blockchain technology offers unprecedented opportunities for enhancing transparency, traceability, and trust in halal supply chains. By embracing blockchain-based solutions, the halal food industry can revolutionize its approach to product management, thereby promoting credibility, trust, and sustainable growth in the Islamic economy.

Methodology

To provide a comprehensive analysis of the phenomenon under analysis, i.e. the impact of the blockchain technology on halal supply chain, we conducted a systematic literature review (SLR) following the guidelines outlined in the PRISMA Statement (Moher *et al.*, 2009). This methodology involves four key steps: identification, screening, eligibility, and, in the case of meta-analyses, inclusion.

The following Figure 2 exemplifies the PRISMA statement approach we adopted, demonstrating the structured process followed in this study.

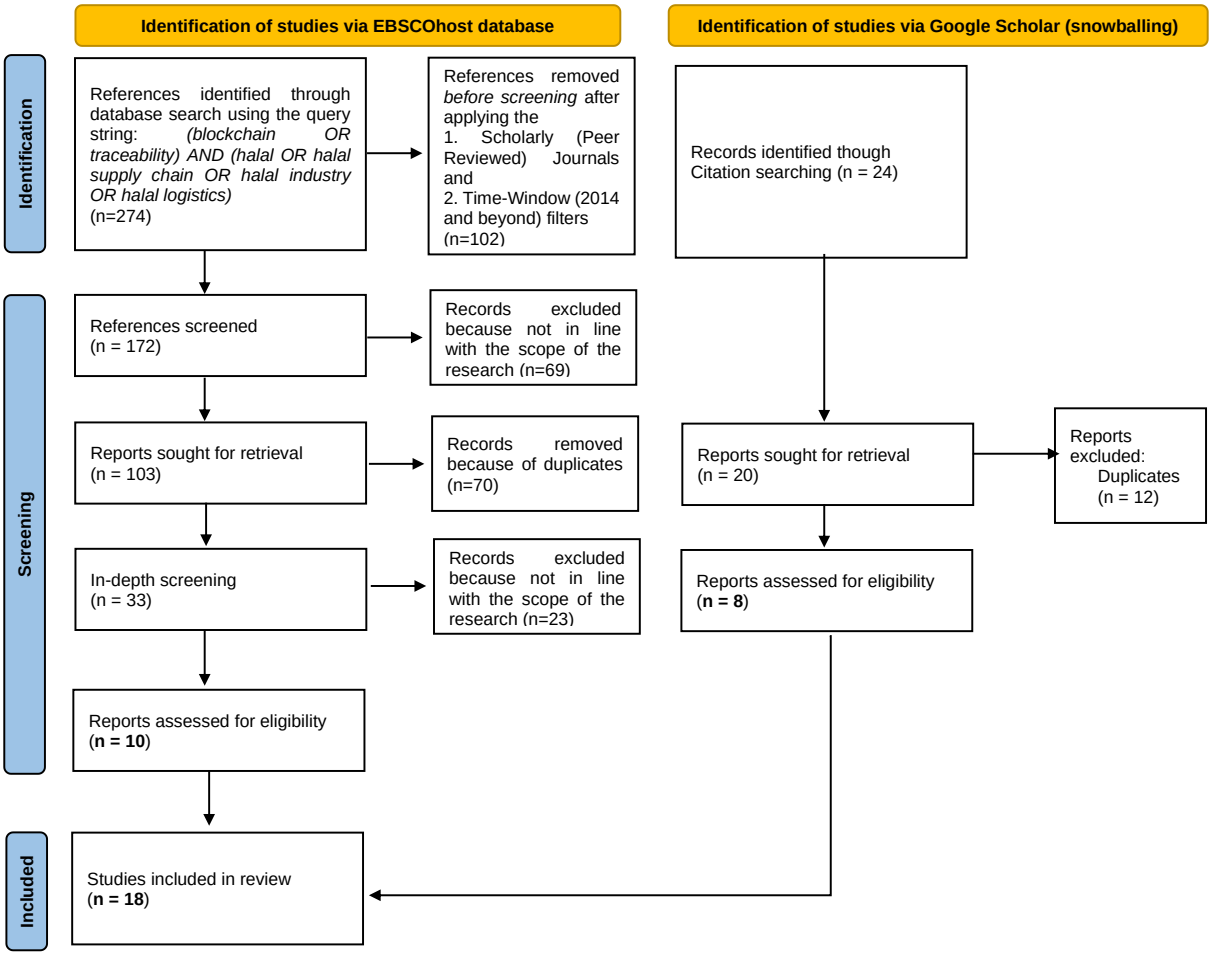

Figure 2 Mapping citations result with PRISMA information flow

Initially, we formulated a search strategy by selecting relevant keywords aligned with our research focus. After conducting preliminary investigations and consulting with experts in the field, we crafted the following query string: (*blockchain* OR *traceability*) AND (*halal* OR *halal supply chain* OR *halal industry* OR *halal logistics*). This string was then employed in eight permutations within the Business Source Premier database (via EBSCOhost), yielding a total of 382 results.

To ensure the quality and relevance of the retrieved references, we applied two filters within EBSCOhost:

- *Scholarly (Peer Reviewed) Journals*: By exclusively selecting papers that had undergone rigorous peer review, we aimed to enhance the reliability of our findings.
- *Time-window*: Although the novelty of the topic could theoretically control for earlier publications, we further refined our search by excluding references older than 2014 to maintain result consistency.

These filters significantly reduced the number of results to 172. Subsequently, in the screening phase, we scrutinized the abstracts of these references to assess their substantive relevance, resulting in 103 relevant papers. Further research on Google Scholar and citation searching of these papers yielded an additional 20 references.

In the eligibility phase, we removed duplicates and thoroughly examined the remaining papers to confirm their suitability for inclusion in our systematic literature review. Ultimately, 18 papers were selected for consideration and review. These papers were managed and coded using Citavi 6.0, serving both as reference management software and as a tool for identifying thematic patterns.

Results and discussion

The following Table 1 exemplifies the relevant papers that form the basis of our analysis. In the next sections, we will discuss the implications of these papers in details.

Table 1 Blockchain and Halal Supply Chain Management

No	Author(s)	Title	Research type	Topic
1.	Asnan *et al.*, 2024	Mapping the Future of Halal Supply Chain Management: A Biblioshiny R Application	Bibliometric Analysis	This research aimed to analyze halal supply chain management publications and visualize the emergent trend for future publication.
2.	Hendayani and Fernando, 2023	Adoption of blockchain technology to improve Halal supply chain performance and competitiveness	Quantitative	This study aimed to investigate the relationship between blockchain technology adoption and firm competitiveness through Halal supply chain performance as a mediating variable.
3.	Purusottoma *et al.*, 2023	Exploring the potential of blockchain adoption for promoting value innovation: a case of the halal industry	Empirical	The study developed a typology model that describes the blockchain adoption for value innovation in the halal industry in Indonesia.
4.	Alamsyah *et al.*, 2022	Blockchain-Based Traceability System to Support the Indonesian Halal Supply Chain Ecosystem	Theoretical	The authors proposed a blockchain-based halal traceability system model specific for the halal meat supply chain.
5.	Bux *et al.*, 2022	Halal Food Sustainability between Certification and Blockchain: A Review	Literature review	This literature reviewed investigates halal food sustainability, examining the barriers and opportunities offered by the certification and blockchain tools.
6.	Sumarliah *et al.*, 2022	Blockchain-empowered halal fashion traceability system in Indonesia	Quantitative	The research examined the participation intent in blockchain-empowered Halal fashion traceability (BHFT) system.
7.	Tan *et al.*, 2022	Applying Blockchain for Halal food traceability	Theoretical	The authors proposed a traceability framework built on Blockchain derived from real-life blockchain implementation in three distinct halal supply chains.
8.	Ali *et al.*, 2021	A sustainable Blockchain framework for the halal food supply chain: Lessons from Malaysia	Theoretical	The authors proposed a novel sustainable blockchain framework for the halal food supply chain that can be used to enhance the supply chain integrity.
9.	Surjandari *et al.*, 2021	Designing a Permissioned Blockchain Network for the Halal Industry using Hyperledger Fabric with multiple channels and the raft consensus mechanism	Experimental / Simulation	The study usesd a Blockchain Network with three channels and used raft consensus algorithm to test their capabilities.
10.	Hew *et al.*, 2020	The blockchain-based Halal traceability systems: a hype or reality?	Quantitative	The study proposes an integrated model aimed at explaining the variance in intention to participate in a blockchain-based Halal traceability system.

11.	Novianti et al., 2020	Designing a Transparent Distributed Systems for Halal Supply Chains Using Blockchain Technology	Theoretical	The paper proposes a distributed system for tracing halal food along its supply chains using blockchain technology.
12.	Vanany *et al.*, 2020	Indonesian halal food integrity: Blockchain platform	Theoretical	Conceptual framework using a specific blockchain architecture, namely Hyperledger fabric, to investigate Indonesian halal food integrity.
13.	Zainal Abidin and Putera Perdana, 2020	A Proposed Conceptual Framework for Blockchain Technology in Halal Food Product Verification	Theoretical	The study presents a framework for blockchain technology for Halal product verification for manufactured food products.
14.	Chandra *et al.*, 2019	Blockchain Redefining: The Halal Food Sector	Experimental	The authors provide a demonstration on how the blockchain technology would shape the halal food supply chain through the hyperledger fabric composer architecture.
15.	Rohmah *et al.*, 2019	Traceability and Tracking Systems of Halal Food Using Blockchain Technology to Improve Food Industry Competitiveness	Theoretical	Conceptual framework of halal food traceability and tracking system using blockchain technology and its impact on food industry competitiveness.
16.	Tieman *et al.*, 2019	Utilizing Blockchain Technology to Enhance Halal Integrity: The Perspectives of Halal Certification Bodies	Theoretical	The paper offers the specific perspective of halal certification toward blockchain technology to improve halal integrity.
17.	Rejeb, 2018	Halal meat supply chain traceability based on HACCP, blockchain and internet of things	Theoretical	The paper suggests a halal meat supply chain traceability system based on HACCP, blockchain and Internet of Things.
18.	Tieman and Ridzuan, 2017	Leveraging blockchain technology for halal supply chains	Theoretical/ Exploratory	The authors provide an overview about the impact of blockchain on halal supply chains providing the basic design principles of blockchain-based HSCs.

Hasnan *et al.* (2024) confirmed the centrality and importance of the impact of blockchain on Halal Supply Chain Management (HSCM). Their thematic map concerning the future trajectory of HSCM delineates four distinct quadrants: i. emerging/declining themes, ii. basic themes, iii. niche themes and iv. motor themes. Notably, the motor theme stands out as a pivotal axis characterized by high significant relevance and high development. This category encompasses pivotal topics including blockchain technology, traceability systems, halal orientation strategy, sustainability, contamination, and Fiqh (Islamic jurisprudence) concerns.

The numerous benefits associated with the adoption of blockchain technology in the context of HSCM have been largely discussed in previous works (Ali *et al.*, 2021; Chandra *et al.*, 2019; Tan *et al.*, 2022; Hendayani and Fernando, 2023; Köhler and Pizzol, 2020), namely:

1. Ensuring the integrity of products and transactions for end consumers through digitalization of halal certificates;
2. Achieving significant cost savings in certification, ranging from 70% to 90%;
3. Streamlining complexity and costs while enhancing capabilities, thus fostering competitive advantage;
4. Facilitating change management and alleviating external pressures;
5. Promoting the adoption of sustainable Halal production and consumption practices.

At the same time, the adoption of blockchain technology also presents potential challenges (e.g. Chandra *et al.*, 2019; Tieman *et al.*, 2019;

Hew *et al.*, 2020; Rahman *et al.*, 2020; Majeed *et al.*, 2021), including:

1. Data privacy and confidentiality: Balancing blockchain's transparency and immutability features with data privacy regulations, such as the General Data Protection Regulation (GDPR) in Europe, which emphasizes customers' right to data erasure.
2. Interoperability/integration: Integrating blockchain into existing supply chain systems requires interoperability with different pre-existing technologies.
3. Scalability and performance: Blockchain scalability is a critical consideration for halal supply chains with high transaction volumes.
4. Cost and resource constraints: Collaborative models can help reduce costs in blockchain projects and foster adoption, especially among SMEs.
5. Regulatory compliance: Blockchain solutions must align with regulatory requirements to ensure compliance.
6. Education and awareness: Education and training programs for different stakeholders are pivotal to facilitate adoption across halal supply chains.

Other relevant challenges specific for halal supply chains are: i. the absence of a global halal certification, leading to inconsistent practices across global halal supply chains (Ab Talib, Mohamed *et al.*, 2017), ii. the presence of inaccurate and unauthentic data concerning Halal products (Ab Talib *et al.*, 2015), iii. inadequate regulation of raw materials for Halal products, partially addressed by the use of the halal logo (Tan *et al.*, 2022), and iv. the ineffectiveness of existing traceability systems, such as RFID or barcode (Norman *et al.*, 2009).

In the literature, four types of blockchain have been categorized based on permission levels (e.g., permissioned or permissionless) and accessibility (e.g., private or public) (Ziegler and Uli, 2021). Tan *et al.* (2022) suggested employing a private permissionless blockchain system to enhance halal integrity. In this regard, Surjandari *et al.* (2021) conducted a simulation in which a permissioned blockchain emerges as an architecture that meets the requirements of global HSCs. Since it is permissioned, administrators can define specific permissions for each participant and, consequently, data visibility. As such, regulators will play a pivotal role in setting such permissions.

A noteworthy model for halal traceability within Indonesia's meat supply chain has been proposed by Alamsyah *et al.* (2022). Their model builds upon earlier conceptual frameworks, specifically focusing on: i) reducing the number of participants within the blockchain network (Rejeb, 2018), ii. establishing a permissioned or private blockchain ecosystem (Novianti *et al.*, 2020), and iii) engaging halal bodies (Surjandari *et al.*, 2021). The Avalanche platform has emerged as the preferred blockchain architecture due to its rapid block creation, cost-effectiveness compared to alternatives (such as Ethereum, Cardano, etc.), support for permissioned blockchains (requiring each actor/stakeholder to obtain licensing for network operation), and accommodation of diverse stakeholder types.

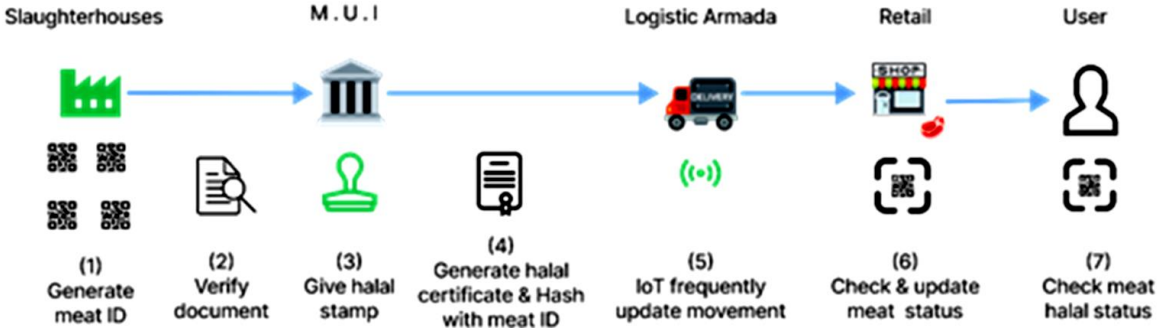

Figure 3 Blockchain process in halal meat distribution. Source: Surjandari et al. 2021

Figure 3 illustrates a potential blockchain process for halal meat distribution in Indonesia. Initially, meat is labelled with a unique ID at the slaughterhouse, which is then uploaded to the blockchain network. Subsequently, the Majelis Ulama Indonesia Institute for Food and Drug Studies and Cosmetics (LPPOM MUI), following document verification, affixes the halal stamp and records an IPFS address on the blocks alongside the MUI's certification. Upon completion of this validation process, distribution commences, with the block regularly updated to reflect handovers until the shipment reaches the retailer. The retailer, in turn, scans a QR code to verify the meat's status, and ultimately, consumers can verify the halal status of the product through the same QR code. A similar foundational framework, albeit applied within a broader context of food supply chains, has also been developed by Novianti *et al.*, 2020, Bux *et al.* (2022), and Tan *et al.* (2022).

It is worth noting that, currently, Indonesia's halal food system relies entirely on halal certificates and labels overseen by LPPOM MUI. Consumers have no immediate access to detailed information and this lack of transparency highlights therefore the need for improved traceability mechanisms (Zainal Abidin and Putera Perdana, 2020).

Conclusion

Yet halal supply chains face numerous challenges, including maintaining halal integrity, ensuring transparency and addressing consumer concerns about trust and authenticity.

Blockchain technology is emerging as a promising remedy to these challenges by enhancing transparency, traceability and integrity within halal supply chains. However, the academic literature on its implementation in this area remains relatively sparse and fragmented, with a lack of empirical research. Our study aimed to provide a current perspective on the impact of blockchain technology on the halal food supply chain industry.

The adoption of blockchain technology offers unparalleled opportunities to improve transparency, traceability and trust in halal supply chains. The adoption of blockchain-based solutions has the potential to revolutionise product management in the halal food industry, thereby promoting credibility, trust and sustainable growth in the Islamic economy.

One notable limitation of our study pertains to the novelty of the topic. However, while we recognize the necessity for further development in empirical and experimental literature, the key findings and insights discussed appear consistent across the range of references analyzed.

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KORIŠTENJE BLOCKCHAIN TEHNOLOGIJE ZA OSIGURANJE INTEGRITETA HALAL LANACA OPSKRBE: SISTEMATSKI PREGLED

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Pregledni rad

SAŽETAK

U protekloj deceniji, potražnja za halal certificiranim proizvodima i uslugama eksponencijalno je rasla u različitim sektorima kao što su hrana, kozmetika, farmaceutski proizvodi i finansije. Prethodna akademska istraživanja su pokazala da su sljedivost, transparentnost i usklađenost sa certifikatima glavni pokretači ponašanja prilikom halal kupovine. U praksi smo, međutim, otkrili da sljedivost, transport i skladištenje, integritet lanca od kraja do kraja, različiti halal sistemi i nedostatak IT integracije doprinose prekidu halal lanaca snabdijevanja. Karakteristike blockchain tehnologije (tj. decentralizacija, nepromjenjivost, transparentnost i kriptografska sigurnost) trebale bi, na papiru, olakšati praćenje i verifikaciju halal proizvoda od njihovog porijekla do krajnjeg potrošača.
U ovom radu istražujemo ključnu ulogu blockchain tehnologije u poboljšanju efikasnosti i pouzdanosti halal lanaca opskrbe.
Rad je osmišljen kao sistematski pregled literature zasnovan na PRISMA metodologiji (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Pregled relevantne akademske literature dodatno je integrisan i obogaćen drugim izvorima kao što su regulatorni okviri i studije slučaja. Čineći to, cilj nam je pružiti ažurirani teorijski i praktični pogled na usvajanje blockchain tehnologije u kontekstu halal lanca opskrbe.
Preliminarni nalazi sugeriraju da bi korištenje rješenja zasnovanih na blockchain-u u halal lancima opskrbe povećalo vidljivost, povjerenje i odgovornost, te posljedično podstaklo veće povjerenje među halal potrošačima. Što se tiče izazova, pitanja skalabilnosti, interoperabilnosti i regulatornih prepreka nesumnjivo bi predstavljale značajne prepreke za zainteresirane strane u industriji.

Ključne riječi: *halal lanci nabavke, blockchain, PRISMA, sistemski pregled*