Enhancing halal agri-food sector: Harnessing blockchain for opportunity and innovation

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ABSTRACT

The halal industry is seeing significant growth, driven by heightened consumption and awareness among Muslims, resulting in a rising demand for high-quality products. The halal agri-food sector is a very promising industry that garners significant customer interest regarding the quality and safety of its products. Nevertheless, the halal agri-food sector is presently encountering considerable hurdles in guaranteeing product authenticity and sustainability, especially in combating fraud, overseeing supply sources, and upholding standards across various locations. Furthermore, recent advancements in technologies like blockchain have garnered substantial interest as a solution for urgent challenges, and their integration could markedly improve procedures and yield benefits for the halal agri-food sector. This study sought to examine the existing literature regarding the potential and challenges of blockchain technology in the halal agri-food sector through a qualitative methodology. The results indicated that blockchain enhanced traceability, increased supply chain efficiency, and supported Sustainable Development Goals 9 and 12. The findings of this study indicate that blockchain integration enhanced the global halal market by optimizing production processes and bolstering consumer confidence, hence propelling the halal agri-food sector to emerge as one of the most profitable and reputable industries worldwide.

ARTICLE INFO

1 Introduction

The global market for halal food is experiencing steady growth over the past year and expected to reach US $1.38 trillion by 2024 (Dinar Standard 2020). This rapid development has significantly influenced the advancement of technology, particularly in catering to the specific needs of the global Muslim population. The evolution of technology spans various sectors, including food production, pharmaceuticals, cosmetics, and finance, aiming to meet the stringent requirements of halal certification. Furthermore, the intersection of religious adherence and technological advancement supports the global Muslim community and drives innovation that benefits the broader market. In order to develop rapidly, opportunity in this growing halal market requires technological assistance (Ruhmah *et al.* 2024).

Blockchain is a distributed ledger technology that records transactions across multiple locations in a secure and tamper-proof manner (Nurdin & Komarudin 2024). This technology depends on a peer-to-peer network where all participants must consensually agree to any changes in the database, ensuring trust and accountability among users (Sarmah 2018). In supply chain (SC), blockchain enhances traceability by providing a transparent, tamper-proof record of product origins and movements. This enhanced traceability is important for industries, such as food and pharmaceuticals, where safety and authenticity are important. SC systems of halal products requires enhanced traceability by blockchain (Ruhmah *et al.* 2024).

In recent years, the popularity of blockchain has increased due to the unique attributes, namely decentralization, transparency, and immutability. Contrary to conventional databases that are regulated by a central authority, blockchain functions on a decentralized network of computers (nodes), with each node maintaining a complete copy of the entire ledger. The decentralized structure renders blockchain highly impervious to tampering and fraud. Nurdin & Komarudin (2024) reported that this technology has attracted attention from industries beyond finance, including healthcare, SC, and even government services due to the potential to enhance security and streamline processes.

Blockchain method includes multiple crucial processes that guarantee the confidentiality and integrity of data. The system comprises a sequence of "blocks", each containing a collection of records and a reference to the preceding block, resulting in an unbroken chain of data (Bahga & Madisetti 2016). A new block is created and broadcasted to all nodes in the network, where each independently verifies the transactions and the cryptographic hash. A block is added to blockchain once the majority of nodes agree that there is validity. In this case, any single entity is prevented from altering blockchain and all participants have a consistent view of the data (Nurdin & Komarudin 2024).

2 Methodology

A qualitative method was adopted, using a comprehensive literature review to explore the potential applications and challenges of integrating blockchain technology into halal agri-food sector. Existing studies, reports, and case studies were systematically analyzed to assess how blockchain can enhance transparency, traceability, and efficiency within halal food SC. Additionally, role of blockchain in ensuring compliance with halal standards, improving sustainability, and contributing to the achievement of relevant Sustainable Development Goals (SDGs) were examined. Through this study, key stakeholders were identified, including farmers, manufacturers, and consumers. The results were synthesized to provide a comprehensive understanding of how blockchain could transform halal agri-food sector, showing the potential and challenges to the widespread implementation.

3 Benefits of Utilizing Blockchain in Halal Agri-food Sector
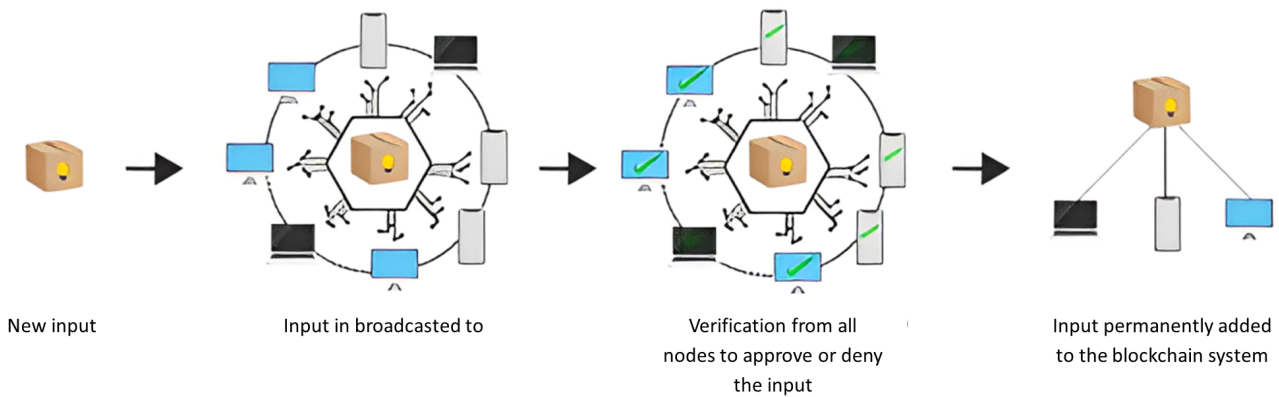
3.1 Transparency

According to Alamsyah *et al.* (2022), ensuring halal integrity is critical in the current halal SC ecosystem of Indonesia, requiring transparency and trust among all stakeholders, from producers to consumers. However, the existing logistics operations and ethical sourcing mechanisms lack these essential qualities. The system depends heavily on centralized databases and manual auditing processes, which are prone to human error, delays,

New input   Input in broadcasted to   Verification from all   Input permanently added
                                                                          nodes to approve or deny   to the blockchain system
                                                                                the input

Figure 1: Network between stakeholders

and potential manipulation. The trust of consumers in the validity of halal-certified products can be potentially eroded by the absence of transparency. The current mechanism, where halal bodies, such as Majelis Ulama Indonesia/Indonesian Ulema Council (MUI) verify and certify products through periodic audits, fails to provide the real-time assurance consumers' demand. In this mechanism, the intervals between audits can be long, enabling non-halal products to enter the market undetected. This statement is consistent with the report of Sarah & Bergmans (2021) that the current halal SC faces several challenges, such as counterfeiting, cross-contamination, and fraud.

Blockchain technology provides a promising solution by ensuring transparency and traceability in the entire food SC. This technology records detailed information, such as food handling, storage, and transportation, which helps guarantee halal status. By storing data in an immutable ledger, blockchain enables stakeholders, including consumers, to verify the authenticity of halal products at every stage of SC, thereby reducing the risk of contamination and fraudulent activities. The centralized tracking of food processing also restricts verification of halal status to those with access to the data, which hinders the development of a transparent and trustworthy SC. Therefore, blockchain-based model is urgently needed to enhance transparency and trust in halal SC. This model will transform the current mushy and potentially unreliable system into a transparent and secure network, guaranteeing the authenticity of halal products, strengthening consumers' confidence, and ensuring ethical sourcing in halal industry. Consistent with the expert opinion of Nashirudin *et al.* (2024), blockchain-based traceability systems provide a transparent and secure way to verify halal status of products in SC, ensuring that information, such as the origin, handling, and processing of halal products is accessible and immutable.

3.2 Efficiency

Efficiency in SC improves by reducing errors, streamlining processes, and providing real-time visibility. For example, in agri-food sector, blockchain can track temperature-sensitive deliveries, optimize resources, and reduce waste. Automating and securing transactions, reducing paperwork, and ensuring only necessary deliveries are refrigerated also reduce operational efficiency, thereby saving resources and money. Efficiency in this context is multifaceted and includes several aspects, such as error elimination, process streamlining, and visibility into SC. Error elimination focuses on reducing mistakes due to human error, system failures, or inaccurate forecasting. This method leads to cost savings, minimizes waste, and optimizes performance.

Quality management and root-cause analysis are methods that help in achieving the study objectives. Moreover, process streamlining focuses on making operations more efficient by eliminating redundancies, as well as improving the speed and transparency of processes. This includes moving towards on-demand manufacturing and eliminating the need for physical documents. SC can be responsive and efficient by adopting non-fragmented product data and consistent information management. Visibility into SC is another aspect of efficiency, where companies can monitor the flow of goods and information in real-time. This ensures better coordination and decision-making, which can lead to improved order fulfillment and consumers' satisfaction. Traceability ensures the verification of product provenance, crucial for ethical sourcing, compliance, and safety. Blockchain provides a transparent and immutable ledger, facilitating product tracking to the source.

3.3 Adhere to Standards and Regulations

The certification process is governed by a set of rules and procedures established through industry standards, national or international regulations, and professional bodies. This process is typically conducted by recognized third-party organizations known for expertise and impartiality. The main objective is to confirm that the subject of certification meets all relevant requirements and can reliably perform as expected. Food

manufacturers often face a substantial problem in adhering to safety regulations and standards, specifically when navigating many regulatory authorities in various locations. Therefore, implementing blockchain technology provides a singular and centralized platform for documenting compliance data, simplifying the process for producers to fulfill regulatory obligations. Blockchain offers the ability to access compliance records in real-time, thereby simplifying the auditing process and minimizing the tendency of items to be non-compliant.

3.4 Rapid Identification of Halal Risk

Blockchain system facilitates the identification and tracking of hazards related to food safety. For instance, blockchain facilitates the rapid identification and recall of products during cross-contamination. By enabling real-time access to a tamper-proof record of the complete history, blockchain technology can assist in resolving the issue of fraud and contamination in SC. A disparity between the recorded data and the actual product can be promptly identified and resolved, thereby reducing the tendency of fraudulent products to reach consumers. This will reduce harm to consumers and preserve the confidence in halal-certified products (Zainal Abidin & Putera Perdana 2020).

Contamination and foodborne illnesses can have catastrophic consequences for agri-food and public health. Traditional methods of monitoring and recalling contaminated products are frequently inefficient, resulting in widespread outbreaks (Sumarliah *et al.* 2023). The use of blockchain ensures that the entire journey of a product can be tracked and visible to all stakeholders. Blockchain also reduces the risk of fraud and counterfeiting by recording every transaction and process step, rendering the alteration or misrepresentation of information virtually impossible. This security further guarantees that the products will satisfy the quality standards, as each procedure is rigorously and extensively monitored (Ali *et al.* 2021).

4 Contributions to Sustainable Development Goals (SDGs)

The implementation of blockchain in halal agri-food sector significantly contributes to achieving SDGs in the future. This includes the achievement of goal number 9, which aims to provide robust infrastructure, promote sustainable industrialization, and support innovation. The implementation of blockchain enables a more dependable infrastructure, thereby reducing the risks associated with fraud, errors, and inefficiencies. The technology also enhances decision-making and expeditious reactions to challenges, such as disruption and contamination in SC (Shahid *et al.* 2020).

Blockchain provides a platform for minor stakeholders, such as farmers, to document and authenticate the products' quality. Transparency can facilitate the entry of small-scale producers into high-quality markets and ensure that appropriate prices are obtained for the products (Sumarliah *et al.* 2023). This will also facilitate enhanced cooperation in the future among stakeholders in halal agri-food sector. Blockchain facilitates innovation and the dissemination of best practices in the sector by providing a collaborative platform for recording and sharing information. Furthermore, this technology positively impacts SDGs number 12, which focuses on promoting sustainable consumption and production patterns. According to a previous study, blockchain enables seamless tracking of the complete duration of halal agri-food products, starting from the farm until it reaches consumers (Patelli & Mandrioli 2020). Blockchain enables the identification of inefficiencies and the optimization of resource utilization by offering extensive data on resource consumption and industrial processes. The optimization enhances the implementation of more environmentally friendly and ethically responsible industrial processes. Information regarding farming and transportation methods, as well as storage conditions, can be closely observed and documented. Moreover, the data enables the assessment of the ecological impacts of food production and encourages the adoption of strategies that reduce resource utilization and lower

greenhouse gas emissions (Yontar 2023).

In cases of contamination, blockchain enables swift and precise recalls of affected items, minimizing further waste and guaranteeing that only necessary products are removed from the market. This enhanced efficiency minimizes the quantity of discarded food as a result of preventive recalls. Retailers also use blockchain to incorporate sustainability data into reporting, thereby providing clear and verifiable information regarding ecological and societal effects. The transparency promotes accountability and incentivizes organizations to adopt more sustainable practices (Stranieri *et al.* 2021).

5 Participation of Stakeholders in the Utilization of Blockchain in Halal Agri-food Sector

The implementation of blockchain has an indirect positive impact on all parties in the manufacturing and distribution of halal agri-food products. Blockchain enables farmers to authenticate and communicate the quality, origin, and sustainability of crops (Ali *et al.* 2021). This degree of flexibility potentially facilitates the penetration into premium markets, where consumers are willing to pay a premium for products that meet particular criteria. Manufacturers can enhance SC by using blockchain to enable real-time tracking and automate procedures, such as payments and inventory management (Antonucci *et al.* 2019). The quality of products can also be enhanced by verifying that the acquired raw materials adhere to the necessary standards, minimizing the potential for contamination and enhancing product quality.

Retailers use blockchain to furnish consumers with comprehensive data regarding the origins and handling of products, thereby enhancing trust and fostering brand loyalty. Sustainability can be authenticated and advertised by retailers, catering to the increasing consumers' need for ethically procured and environmentally friendly products (Shahid *et al.* 2020). Meanwhile, the ability of blockchain technology to enhance traceability and transparency in agri-food SC strengthens food safety measures, which is particularly beneficial in maintaining consumers' trust in halal food products (González-Mendes *et al.* 2023). Consumers also benefit from having access to clear and confirmable information regarding the procured product, such as the source and manufacturing methods. This enables an individual to make more informed decisions that are consistent with personal views and principles. Blockchain enhances the efficiency of auditing procedures by enabling authorities to retrieve comprehensive and trustworthy information regarding SC operations promptly. According to a previous study, blockchain data provides valuable insights for policy-making, allowing governments to create focused actions that support sustainability and food security (Bux *et al.* 2022). The application of blockchain also showed significant potential in reducing transaction costs and improving the transparency of agri-food SC, leading to increased efficiency in network coordination (Kramer *et al.* 2021).

6 Challenges of Utilizing Blockchain in Halal Agri-food Sector

Blockchain in halal agri-food sector provides many benefits but the technology has several drawbacks, including barriers to universal adoption. Issues, such as cost and scalability, need to be addressed before blockchain can achieve widespread implementation. Issues, such as cost and scalability, need to be addressed before blockchain can achieve widespread implementation as the limited adaptability of blockchain can undermine the efficacy of the systems. In some cases, adaptability issues. In some cases, adaptability issues influence vitality exchange by constraining the throughput of vitality and possibly influencing the peer-to-peer exchanges in genuine time (Alghamdi *et al.* 2016). Adopting blockchain technology can be costly and intricate, necessitating substantial investments in both technology and training. The return on investment should be considered while adopting new technologies specifically for Small and Medium Enterprises (SMEs), which often have limited resources. According to Ji *et al.* (2020), the lack of confidence regarding the return on investment in blockchain creates further concerns regarding the execution and adoption. Constructing halal traceability system based on blockchain necessitates a substantial allocation of diverse resources, which incurs high expenses for the organization and deters stakeholders from engaging (Hew *et al.* 2020).

Blockchain systems face scaling challenges, particularly when the network grows significantly, leading to slow transaction times and high fees (Tripathi *et al.* 2023). Integrating blockchain with systems and processes in agriculture can be complex, and existing practices may require modification. Blockchain provides transparency but can also pose data privacy and security challenges, specifically when managing

sensitive information. Agri-food sectors, such as SMEs may need more precise regulations and standards governing blockchain systems, leading to potential legal and compliance issues. For instance, in food industry, the implementation of blockchain has limited profitability, particularly for supermarkets and restaurants (Kim & Laskowski 2018; Nash 2018). However, the continued exploration and experimentation with blockchain show a growing commitment to overcoming these barriers and integration into various aspects of business and governance (Sarmah 2018).

7 Conclusions

In conclusion, halal food represents a global dietary trend that is currently undergoing rapid expansion with significant economic potential. This advancement substantially enhanced the agri-food sector and associated industry by utilizing cutting-edge technology and innovation. Through the use of blockchain technology, it enabled a transparent and secure distribution system, positively influencing the halal industry as consumers became more informed and conscientious in their product choices.

Conflict of Interest

The authors declare no conflict of interest.

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