Advancing halal agri-food sector: Using technology and innovation for sustainable growth and new opportunities

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A B S T R A C T

Halal agri food sector is influenced by rapid transformation driven by growing global demand, increased consumer awareness of health and ethical considerations, as well as advances in technology. Therefore, this research aimed to discuss the importance of maintaining halal integrity in food production, processing, and distribution, particularly in the era of Industry 4.0. Key drivers of innovation were explored, including the expanding Muslim population, evolving consumer preferences, and increasing sustainability concerns. The impact of technology such as blockchain, Internet of Things (IoT), and Artificial Intelligence (AI) on enhancing traceability and transparency in halal supply chain was reported. Strategies for future development comprised raising public awareness, integrating halal assurance systems with advanced technology, and strengthening collaboration among governments, industry stakeholders, and certification bodies. Significant challenges were also addressed, including fragmented global halal standards, complex certification processes, and high implementation costs. Halal agri-food sector can achieve sustainable growth and remain competitive in the global market by accepting technological innovation and enhancing cooperation among stakeholders.

ARTICLE INFO

1 Introduction

Ensuring adherence to halal standards in food production, processing, and distribution is important, particularly in the context of Industrial Revolution 4.0. The significance of producing halalan tayyiban food (permissible and wholesome) is reduced when halal and hygiene standards are not rigorously maintained in the entire supply chain, from the point of origin to the end consumer.

Currently, halal has evolved into a universal concept, transcending Islamic origins. The implementation of halal supply chain management is essential to maintain the integrity of the products in the market. This requires distinct handling and separation of halal and non-halal items in supply chain.

Indonesia's food industry has significant opportunities to apply advanced technology in processing and distribution, due to the advancements and innovations introduced by the Industrial Revolution 4.0. Rigorous halal supply chain management is crucial to ensure compliance with standards at every stage of production and distribution. For instance, maintaining a clear separation between halal and non-halal products during storage, packaging, and shipping is necessary to prevent cross-contamination, which can compromise halal status of a product. Strict oversight is important in the selection of raw materials and during the processing stage, where every ingredient and tool must uphold cleanliness and halal integrity. This compliance reassures consumers that the products genuinely meet halal standards, which is critical from a religious perspective and in terms of hygiene and quality

2 Factors Influencing Opportunities and Innovation in Halal Agri-Food Sector

Numerous factors influence opportunities and innovation in the halal agri-food sector. The growing global Muslim population consistently shows demand for halal-certified products. Significant market growth is occurring

in Southeast Asia, the Middle East, and Africa, driven by demographic expansion and a rising consumer demand for high-quality, safe, and healthy halal products. Increased awareness of religiously compliant and healthy options with a preference for halal-certified organic and ethically sourced items, is pushing businesses to innovate. In this context, halal certification is combined with sustainable and organic farming to cater to this fast-growing, specialized market.

Technological advancements are key to shaping sector opportunities. In this context, blockchain enhances supply chain transparency and traceability, ensuring strict adherence to halal standards. Biotechnology innovations also offer new alternative protein sources such as plant-based or lab-grown meat, addressing environmental concerns. However, a major challenge for global businesses is the fragmentation of halal standards across regions. This lack of a unified global standard complicates certification for producers and confuses consumers. The development can streamline operations and increase international growth. The economic landscape and market trends significantly impact the sector. Globalization has opened new markets for halal products in non-Muslim-majority countries with sizable Muslim populations. Additionally, the increasing popularity of e-commerce provides new distribution channels, allowing businesses to reach wider audiences more efficiently.

3 Strategies for Future Generations to Improve Halal Agri-Food System

The initial strategy to enhance halal agri-food system comprises raising awareness. A prevalent misconception, particularly among populations in Muslim-majority nations such as Indonesia, Malaysia, and Brunei, is the assumption that food in the borders is inherently halal. However, this is inaccurate since numerous issues arise concerning food consumption.

According to Rasyid (2010), a significant proportion of consumers presume all products sold are halal due to the country's Muslim-majority population. Halal food industry holds considerable significance for Muslim-

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majority countries and shows potential in non-Muslim regions due to perceived association with high standards of safety and hygiene. Several strategic methods have been implemented to effectively promote and advance halal concept.

a. The integration of blockchain and Internet of Things (IoT) revolutionizes halal food supply chains by enhancing transparency and traceability. This technological advancement promotes credibility and trust in Halal certification, increasing halal economy (Davids & Sabrain 2022).

b. A blockchain-powered Halal Assurance System (HAS) promotes sustainable production in line with Maqasid al-Sharia principles that prioritize consumer protection and religious values (Qanita *et al.* 2024). Integrating HAS with blockchain technology is crucial for advancing the halal concept in the agri-food sector. This method ensures transparency and traceability, effectively combating fraud in halal certification.

Crucial steps for the halal agri-food sector include improving sustainable production management and increasing education and training for business operators in halal practices. These initiatives reinforce adherence to Maqasid al-Sharia principles, promoting consumer protection and religious values. Despite the viable strategies for advancing the halal concept, persistent challenges such as limited awareness and misinformation about halal products continue to affect progress. Addressing the issues requires efforts from regulatory bodies, industry stakeholders, and educational programs to ensure the sector's sustainable growth. This problem often appears within the halal agri-food sector. For example, livestock must meet halal certification, and their feed should come from halal-compliant sources. Furthermore, raising awareness about these complexities demands significant participation from all relevant stakeholders, especially government agencies. According to Rasyid (2010), Muslim consumers are relying more on Indonesian Council of Ulama (MUI), which brings assistance, guidance, and advice in religious matters and to assess halal status of a product. Therefore, the integration of consumers, institutions, and other relevant parties, such as the government, is needed to improve halal agri-food in the future. Halal certification simplifies the identification of food from raw materials to the final product.

Certification serves as crucial evidence that food is safe for consumption in the journey to the consumer. Supply chain often presents the biggest challenge in halal industry. Cross-contamination occurs when food is subjected to numerous processing steps without proper monitoring. These issues can be prevented by building greater consumer trust in the future by normalizing halal certification. According to Omar (2013), JAKIM (Department of Islamic Development Malaysia) is intensifying the efforts to raise public awareness regarding the significance of consuming halal-certified food, with particular emphasis on products bearing the official JAKIM halal mark. In this context, JAKIM has implemented measures against individuals and entities found to be fraudulently using halal logos and Islamic brands for commercial gain. The department plans to introduce additional regulations to strengthen halal compliance. These prospective rules include: 1) all ingredients used in food production must come from halal sources that are permissible for Muslim consumption and must not be combined with any non-halal substances containing impure elements; 2) the development and manufacturing of all equipment used in food processing, production, or related activities must strictly avoid the use of any unsafe or prohibited materials; and 3) prohibited items must not come into contact with food at any stage of handling, including transportation, storage, or consumption.

In halal agri-food, all raw materials, sources, and halal supply chain must meet the Shariah requirements. To enhance the future of halal agri-food and prevent issues, food producers, stakeholders, and consumers require awareness. This necessitates strict adherence to halal law and continuous collaboration among all parties.

4 Impact of Enhancing Halal Agri-Food System on Agri-Food Innovation

Significant innovation in food processing and product development is obtained from halal compliance. Furthermore, Shariah-compliant technologies are crucial for improving supply chain efficiency. This includes a strategic process for transforming non-halal ingredients into entirely halal products, a move expected to positively impact the growing market.

5 Challenges in Implementing Halal Standards in Agri-food Sectors

Integrating halal standards into the agri-food sector presents challenges, primarily due to the difficulty of balancing religious guidelines with competitive business needs. Subsequently, the Industrial Revolution's fast-paced technological advancements complicate ensuring innovations meet specific halal industry requirements. Addressing the issues demands an effort from various stakeholders. Governments must set and enforce halal regulations, while producers ensure consistent adherence. Research is crucial for managing compliant technologies and developing innovative products. Moreover, consumers fuel market demand for high-quality

halal-certified goods. The main challenges of halal implementation are analyzed in the agri-food sector, starting with procedural and certification issues.

5.1 Procedural and Certification Challenges

Procedural and certification challenges consist of complex certification processes and risk of contamination. Complex certification processes refer to the challenges encountered in the existing halal certification system, which often involves significant complexity and a lack of uniformity across various geographical regions. These inconsistencies in standards frequently disrupt international trade and create substantial barriers, particularly for small and medium sized enterprises (SMEs) operating in the global halal food sector (Salma *et al.* 2024).

Risk of contamination refers to the ongoing threat of contamination with non halal substances that can occur at different stages of production and distribution in the agri food sector. This risk is especially high during the transportation and handling of agricultural commodities, where established halal protocols are not always strictly observed. Such incidents can compromise the halal integrity of products and result in significant financial losses (Budiyoko *et al.* 2022; Plojović *et al.* 2017).

5.2 Regulatory and Compliance Issues

Regulatory and compliance issues consist of inconsistent halal laws and non-compliance concerns. Inconsistent halal laws refer to the implementation of halal laws varies significantly across countries. For instance, Malaysia has national halal laws, while Netherlands do not possess formal halal legislation. This inconsistency complicates compliance for international businesses. Non-compliance concerns refer to the Ensuring compliance with halal standards in supply chain is challenging, with issues such as improper slaughtering methods and mislabeling being prevalent. Advanced authentication methods are developed to address noncompliance concerns (Fathima *et al.* 2024).

5.3 Technological and Supply Chain Challenges

Technological and supply chain challenges include traceability and transparency as well as integration with good agricultural practices. Traceability and transparency are important because the halal supply chain is complex, and reliable systems are needed to track products and ensure compliance at every stage. Blockchain technology has been suggested as a solution to improve traceability and manage data throughout the halal food supply chain (Adhiwibowo *et al.* 2023). Integration with good agricultural practices is also essential. Halal standards need to be aligned with existing agricultural practices and safety standards. This alignment helps simplify processes and ensures that halal requirements are fulfilled without reducing agricultural efficiency (Alzeer *et al.* 2020).

5.4 Market and Consumer Perception

Market and consumer perception include consumer awareness and perception as well as cost and market competitiveness. Consumer awareness and perception are important because there is an increasing demand for halal products among both Muslims and non-Muslims who associate halal with cleanliness and safety. However, the level of awareness and perception differs among consumers, which can influence market trends and overall competitiveness (Yusuf *et al.* 2015). Cost and market competitiveness are also key factors. Implementing halal standards often involves significant costs, which can affect how competitive a business is in the agri-food sector. Companies need to carefully balance these costs with the potential market advantages gained from offering halal-certified products (Yusuf *et al.* 2015).

The challenges in implementing halal standards in agri-food sector are significant but present opportunities for innovation and improvement. The integration of advanced technology such as blockchain for traceability and the harmonization of halal standards with good agricultural practices enhances compliance and efficiency. Furthermore, addressing regulatory inconsistencies and improving consumer awareness can increase the growth potential of halal market. The efforts require collaboration among stakeholders, including governments, industry players, and certification bodies, to create a more cohesive and effective halal implementation framework.

5.5 Challenges of Adopting Technology Solutions in Halal Certification

Traceability systems and other advanced technologies impact halal certification in agri-food by increasing transparency, ensuring authenticity, and simplifying logistics. Blockchain, AI, and ERP can streamline certification, optimize supply chains, and build consumer trust. However, significant investment, complex implementation, and the need for industry consensus for interoperability affect broad adoption. Future sections will detail the impact of technology on halal certification.

5.5.1 Enhancing Transparency and Authenticity

a. Blockchain Technology
Blockchain provides a decentralized and immutable ledger that enhances transparency and prevents fraud in halal certification process. This technology allows for real-time verification and traceability of halal products from source to consumer, addressing issues of fraudulent certifications and complex supply chain management (Mehmood *et al.* 2024; Alourani & Khan 2024).

b. Artificial Intelligence (AI)
AI supports pattern identification and ensures the authenticity of halal products by providing traceability related to all operations and processes in supply chain (Alourani & Khan 2024).

c. Smart Contracts
Smart Contracts are used in blockchain frameworks to resolve traceability issues such as data leakage and manipulation, ensuring organizational consistency and adherence to Sharia laws (Munawar & Mugiono 2024).

5.5.2 Improving Supply Chain Management

a. Enterprise Resource Planning (ERP)
ERP systems are used to trace and monitor halal supply chains, ensuring compliance with certification standards and optimizing operations. This is particularly effective in complex supply chains used for beef products (Kusnadi *et al.* 2024).

b. Internet of Things (IoT)
The combination of IoT with blockchain facilitates the collection, storage, and transmission of comprehensive records in halal food supply chain, enhancing traceability and safety (Adhiwibowo *et al.* 2023).

5.5.3 Addressing Logistical and Implementation Challenges

a. Cost and Complexity
The adoption of traceability systems includes significant costs and complexity, which can be barriers for some businesses. The need for industry players to develop and be familiarized with the technology is crucial for effective implementation (Nazri *et al.* 2024).

b. Scalability and Integration
Technology such as Hyperledger Fabric improves the openness of the certification process but cannot necessarily speed up the certification awards. Further research is needed to address scalability and integration issues in real-world applications (Ramantoko *et al.* 2024).

5.5.4 Government and Industry Support

a. Policy and Regulation
Government support plays a crucial role in the adoption of technology for halal certification. Policies promoting the use of technology can enhance the integrity and legitimacy of halal products (Nugroho *et al.* 2024).

b. Industry Collaboration
Collaboration among industry players, including halal agencies and businesses, is essential for the successful implementation of traceability systems. This includes creating networks and frameworks required to facilitate the sharing of information and resources (Ramantoko *et al.* 2024).

Technological advancements offer promising solutions to enhance halal certification process and require careful consideration of regulatory frameworks, industry collaboration, and cost implications. The successful adoption depends on overcoming the challenges and ensuring stakeholders are consistent with efforts of maintaining the integrity of halal products.

6 The Implementation of Technology in Halal Certification Process

Technology's integration into halal certification is transformative, addressing challenges such as transparency, traceability, and fraud. Blockchain, IoT, AI, and big data analytics streamline processes and enhance product integrity. These advancements increase operational efficiency and consumer trust in halal certifications. The following sections analyze specific technologies and the applications.

6.1 Blockchain Technology

a. Transparency and Security
Blockchain provides an immutable and decentralized ledger that securely records and verifies halal certification information, addressing issues of transparency and fraud in the certification process (Mehmood *et al.* 2024) (Mohaiyadin *et al.* 2024).

b. Smart Contracts
Smart contracts are used to automate and enforce the certification process, ensuring that all conditions are met before issuing a certificate. This reduces the potential for human error and manipulation (Agung *et al.* 2024).

c. Traceability
Blockchain enables end-to-end traceability of products, allowing consumers and stakeholders to verify halal status (Mehmood *et al.* 2024) (Munawar & Mugiono 2024).

6.2 Internet of Things (IoT) and Big Data

a. Enhanced Monitoring
IoT devices monitor various stages of supply chain, providing real-time data analyzed using big analytics to ensure compliance with Halal standards (Popolo *et al.* 2024).

b. Data Integration
The integration of IoT and big data analytics facilitates the collection and analysis of large volumes of data, improving decision-making processes related to halal certification (Popolo *et al.* 2024).

6.3 Information Systems and Integration

a. System Development
The development of web-based information systems, such as the integration of Halal Inspection Institute's system with the SiHalal platform, enhances operational management and credibility of halal certification bodies (Tedy & Hidayah 2024).

b. Operational Efficiency
Operational efficiency streamlines the certification process, making the system more efficient and reducing the time required (Tedy & Hidayah 2024).

7 Conclusions

In conclusion, the halal agri-food sector is experiencing significant transformation due to high global demand, greater consumer awareness of health and ethical concerns, and technological advancements. Maintaining product integrity through adherence to halal standards throughout the supply chain is crucial, especially with rapid developments such as blockchain and biotechnology. However, fragmented global halal standards and complex supply chains pose challenges. Overcoming the challenges through enhanced collaboration, improved certification processes, and accepting innovation will enable the halal agri-food sector to achieve sustainable growth and meet evolving global market demands.

Conflict of Interest

The authors declare no conflict of interest.

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