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Enhancing Halal Traceability in Broiler Supply Chains: The Role of Blockchain Technology

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ABSTRACT

The global demand for Halal food continues to rise, yet ensuring authenticity and traceability within broiler supply chains remains a significant challenge. This study investigates the potential of blockchain technology to strengthen Halal traceability, addressing existing gaps in fragmented and tamper-prone systems. Using Malaysia's broiler industry as a case study, the research adopts a qualitative approach based on semi-structured interviews with fifteen industry experts, complemented by document analysis and thematic evaluation. The findings reveal that blockchain's decentralized and immutable ledger enhances transparency, reduces fraud, and provides real-time verification of Halal compliance. Participants emphasized that blockchain not only secures certification records but also improves consumer trust through accessible and verifiable product information. While financial and technical barriers hinder adoption, the study concludes that blockchain offers a transformative pathway for industry players and regulators to ensure Halal integrity, strengthen consumer confidence, and guide future digitalization of Halal supply chains.

1. Introduction

The Halal food industry has emerged as one of the fastest-growing sectors in the global economy, driven by the expanding Muslim population, increasing consumer awareness, and the rising demand for ethically sourced products. According to the State of the Global Islamic Economy Report, the value of the Halal food market is expected to reach USD 2.6 trillion by 2025, with broiler products accounting for a significant portion of this growth [1]. As the sector expands, ensuring authenticity, compliance, and traceability has become a pressing concern in maintaining consumer trust and safeguarding Islamic dietary laws [2].

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Scholars have consistently highlighted persistent challenges in Halal broiler supply chains, including fraud, mislabeling, and weak monitoring systems [3]. Studies in Southeast Asia reported that nearly one-third of Halal-certified broiler products failed to meet required standards due to fragmented and tamper-prone traceability mechanisms [4]. Blockchain technology has been introduced as a promising solution, with research demonstrating its ability to create secure, immutable records of product origins, feed composition, slaughtering methods, and logistics information [5]. Despite these contributions, much of the existing literature remains theoretical and limited in empirical application, especially in Halal-specific contexts [6].

This gap underscores the need for further investigation into how blockchain technology can address the distinctive requirements of Halal assurance in broiler supply chains. While the concept of blockchain adoption in food supply chains has gained attention, limited evidence exists on its practical challenges, opportunities, and impact on Halal integrity in Malaysia.

Therefore, the purpose of this study is to examine the role of blockchain technology in enhancing Halal traceability in broiler supply chains. Specifically, the research investigates how blockchain can improve transparency, reduce fraud, and strengthen consumer trust while also identifying the barriers and enablers of its adoption.

1.1 Background of Study

The Halal food industry has become one of the fastest-growing and most dynamic sectors in the global economy, driven by the expanding Muslim population, increasing consumer awareness, and rising demand for ethically sourced and religiously compliant products [7]. According to the *State of the Global Islamic Economy Report*, the Halal food market is projected to reach USD 2.6 trillion by 2025, with broiler products contributing a significant portion of this growth [1]. However, alongside this expansion, ensuring the authenticity, traceability, and compliance of Halal products has emerged as a critical challenge. These issues are particularly evident in broiler supply chains, which face risks such as fraud, mislabeling, and difficulties in maintaining adherence to Islamic dietary principles due to the complex processes of production, processing, and distribution [3]. In this context, blockchain technology has been recognized as a transformative innovation, offering enhanced traceability, stronger compliance mechanisms, and improved consumer trust in Halal certification systems [3,4].

1.2 Understanding Halal Traceability

Halal traceability refers to the ability to monitor and verify the Halal status of a product throughout its supply chain, from the farm to the consumer's table. This process involves ensuring that all stages, including animal rearing, slaughtering, processing, and packaging, comply with Shariah principles [8]. The concept is rooted in the Islamic values of *tayyib* (wholesomeness) and *amanah* (trustworthiness), which emphasize transparency, accountability, and ethical conduct in food production [4]. In the broiler industry, Halal traceability parameters include the origin of chicks, feed composition, slaughtering methods, and transportation systems. However, achieving effective Halal traceability has proven challenging. Conventional systems are often fragmented and vulnerable to tampering, leading to fraud, mislabeling, and non-compliance. Research in Southeast Asia revealed that approximately 30 percent of Halal-certified broiler products failed to meet required standards due to weak monitoring and traceability mechanisms [3]. Such shortcomings undermine consumer confidence and threaten the credibility and profitability of Halal food companies.

1.3 Towards Halal Traceability: The Role of Blockchain Technology

Blockchain technology, characterized by its decentralized, immutable, and transparent ledger system, presents a promising solution to Halal traceability challenges [5]. Originally developed for digital currencies, blockchain has since been applied across industries, including supply chain management. It enables real-time tracking and verification of product information by creating tamper-proof digital records that enhance accountability at every stage [9]. For Halal broiler supply chains, blockchain can securely store and validate critical information such as chick origin, feed details, slaughtering practices, and logistical processes. This capability strengthens compliance with certification requirements. Recent researcher argues [10] argues that digital technologies like blockchain are no longer optional but essential for businesses to remain competitive in the global food industry. Furthermore, blockchain supports adherence to regulatory frameworks such as the Halal Assurance Management System (HAS 23000) and Malaysia's Halal Certification Procedure [11], which emphasize effective traceability systems to safeguard Halal integrity.

1.4 Challenges and Opportunities

Although blockchain offers substantial advantages, its implementation in Halal broiler supply chains is not without challenges. Key barriers include high initial investment costs, lack of technical expertise, and resistance to organizational change [6]. The adoption of blockchain requires collective commitment from all stakeholders in the supply chain, including producers, distributors, regulators, and certification bodies. Such collaboration often entails cultural and structural adjustments, which can be difficult to achieve. Nevertheless, the benefits of blockchain outweigh the obstacles, making it a viable solution for addressing traceability concerns [6]. When successfully implemented, blockchain has the potential to reduce instances of fraud and mislabeling while strengthening consumer confidence in Halal certification.

1.5 Current Trends and Future Directions

Blockchain adoption for Halal compliance is still in its early stages, but several pioneering initiatives have demonstrated its potential. In Malaysia, the Halal Blockchain Project launched in 2022 aims to create a blockchain-based system to track Halal products from production to consumption [12]. Similarly, the United Arab Emirates introduced the Halal Blockchain Platform, which authenticates food products' Halal status and ensures compliance with Islamic dietary regulations [13]. These projects highlight a growing recognition of blockchain's role in enhancing trust and efficiency in Halal supply chains. Looking ahead, the integration of blockchain with other advanced technologies, such as the Internet of Things (IoT) and artificial intelligence (AI), presents exciting opportunities. IoT devices can capture real-time data on production and logistics, while AI can analyze blockchain records to identify potential risks or irregularities, allowing for proactive compliance monitoring [14]. Such synergies may shape the future of Halal traceability by enabling more resilient, transparent, and technology-driven food systems.

1.6 Research Problem

Despite the global rise in demand for Halal broiler products, the lack of robust traceability systems continues to pose critical challenges. Consumers often face difficulties in verifying the authenticity of Halal claims, which undermines their trust. At the same time, businesses struggle to maintain

compliance across complex supply chains where processes are fragmented and susceptible to manipulation. Traditional systems do not provide real-time visibility, leaving opportunities for fraud, mislabeling, and lapses in Halal assurance [3,4]. These weaknesses highlight the urgent need for technological interventions such as blockchain to strengthen Halal traceability and protect both consumer trust and the reputation of Halal food enterprises.

1.7 Research Questions and Objectives

1.7.1 Research Questions:

1. How can blockchain technology enhance traceability in Halal broiler supply chains?
2. What are the challenges and opportunities of implementing blockchain for Halal traceability?
3. How does blockchain improve consumer trust in Halal broiler products?

1.7.2 Research Objectives:

1. To explore the potential of blockchain technology in enhancing Halal traceability.
2. To identify the challenges and opportunities of blockchain adoption in broiler supply chains.
3. To assess the impact of blockchain on consumer trust and compliance with Halal standards.

1.8 Significance of Research

This study investigates the role of blockchain technology in enhancing Halal traceability in broiler supply chains, addressing one of the most pressing challenges in the global Halal food industry. With the market projected to reach USD 2.6 trillion by 2025, ensuring authenticity, transparency, and compliance has become critical for sustaining consumer trust and industry growth [1].

Blockchain offers a decentralized and tamper-proof system that strengthens Halal assurance by reducing fraud, preventing mislabeling, and enabling real-time verification of product status [4][5]. This capacity not only enhances adherence to Shariah standards but also supports the credibility of certification systems, directly benefiting producers, regulators, and consumers [6]. By providing transparent information, blockchain builds consumer trust, minimizes economic losses associated with fraud, and ensures accountability across the supply chain [15].

Beyond compliance, blockchain contributes to sustainability and ethical practices by promoting humane rearing, responsible sourcing, and environmentally sound production [16]. It also reflects a broader trend toward digital transformation, positioning blockchain as a driver of innovation and efficiency in the food industry [17]. Importantly, the findings of this research offer valuable insights for policymakers and certification bodies such as JAKIM and IFANCA in designing regulatory frameworks that encourage blockchain adoption, ensuring the long-term integrity and competitiveness of Halal supply chains.

1.9 Limitations of the Study

While this research provides valuable insights into the potential of blockchain technology for improving Halal traceability in broiler supply chains, several limitations must be acknowledged. First, the scope of the study is restricted to broiler products, which represent only one segment of the Halal food market. Therefore, the findings may not fully apply to other sectors such as beef, seafood, or processed foods with different supply chain complexities [18].

Second, the study relies on a qualitative approach using semi-structured interviews and document analysis. Although this method provides rich contextual insights, it lacks the quantitative rigor necessary to objectively measure the impacts of blockchain on traceability and compliance [19].

Third, the research is geographically focused on Malaysia, where regulatory frameworks and consumer preferences differ from other regions, limiting broader generalizability [20].

Finally, financial and technological barriers pose significant challenges to blockchain adoption. High infrastructure costs, the need for technical expertise, and stakeholder training requirements are major obstacles for small and medium-sized enterprises. Moreover, although blockchain enhances transparency, it also raises ethical and privacy concerns that warrant further exploration [21].

2. Literature Review

2.1 Halal Traceability: Concepts and Challenges

Halal traceability refers to the ability to track and verify a product's Halal status across its entire supply chain, ensuring compliance with Shariah principles from animal rearing to processing and distribution. Rooted in the values of *tayyib* (wholesomeness) and *amanah* (trustworthiness), it emphasizes transparency, accountability, and integrity in food production [22]. Despite its importance, implementation remains difficult. Conventional systems are often fragmented, opaque, and prone to tampering, resulting in mislabeling, malpractice, and non-conformance. For instance, 30 percent of Halal-certified broiler products in Southeast Asia did not meet required standards due to weak monitoring systems [3]. Addressing these weaknesses is crucial for protecting consumer confidence and industry credibility.

2.2 Exploring Blockchain Technology for Traceability

Blockchain technology, originally developed for cryptocurrencies, offers a decentralized, immutable, and transparent digital ledger that records transactions in real time. Its ability to create secure, tamper-proof records makes it particularly valuable for Halal broiler supply chains, where details such as chick sources, feed composition, and slaughter methods can be verified with accuracy [5]. Studies show blockchain enhances transparency and reduces fraud in food supply chains [23]. Specifically, in Halal contexts, it secures compliance by ensuring immutable documentation of product origins and processing methods [24].

2.3 Current Applications of Blockchain in Halal Broiler Supply Chains

Although still at an early stage, blockchain adoption in Halal supply chains is gaining traction. Malaysia's Halal Blockchain Project, launched in 2022, aims to trace products from farm to table, while the UAE's Halal Blockchain Platform authenticates Halal status to guarantee compliance with dietary regulations [13]. Despite challenges such as high costs and limited expertise, these initiatives highlight blockchain's growing acceptance. Its ability to enhance transparency, reduce fraud, and strengthen consumer trust positions it as a viable solution for addressing current traceability challenges [25].

2.4 Theoretical Framework and Models

Several frameworks explain blockchain adoption in supply chains. The Technology-Organization-Environment (TOE) framework identifies factors such as technological compatibility, organizational readiness, and regulatory support that influence adoption [26]. Additionally, Rogers' Diffusion of Innovations (DOI) theory explains how new technologies are adopted based on relative advantage, compatibility, complexity, trialability, and observability [27]. These frameworks provide insights into how blockchain can be integrated effectively into Halal broiler supply chains.

2.5 Gaps in the Literature

Although the literature on blockchain and food traceability is expanding, several gaps remain. Most studies emphasize theoretical potential rather than empirical outcomes. Limited research examines the practical challenges of blockchain adoption in Halal broiler supply chains. Furthermore, stakeholder perspectives, particularly those of farmers and retailers, are underexplored. Another gap lies in the integration of blockchain with emerging technologies such as IoT and AI for Halal compliance [14].

2.6 Emerging Trends and Future Directions

Recent trends suggest promising developments for Halal traceability. IoT devices can capture real-time production data, which can then be stored on blockchain to enhance accountability. AI algorithms can analyze blockchain data to detect fraud or risks, enabling proactive interventions [28]. Moreover, blockchain-based certification systems are being developed to provide reliable and secure verification processes, improving efficiency and consumer trust. The future of Halal traceability will likely depend on integrating blockchain with complementary technologies to build transparent, resilient, and digitally driven supply chains [29].

3. Methodology

3.1 In-Depth Interviews with Industry Experts

Semi-structured and in-depth interviews were conducted with key industry experts focusing on how the blockchain can be applied to halal broiler supply chains, in order to gauge the practical applicability of blockchain solutions in the context of food traceability [30]. This study utilized semi-structured interviews to obtain in-depth insights on the practical challenges, as well as the current opportunities for blockchain implementation in Halal broiler supply chains from producers, regulators, and technology providers across the sector. Furthermore, a study of current blockchain-based systems for the food industry was undertaken to gain understanding of best practices in implementation and the potential adaptations needed for these systems in a Halal compliant environment [31]. This study also presented how blockchain can be applied practically, by developing an analyse of a blockchain-based traceability system, to improve transparency and accountability in broiler supply chains.

3.2 Data Analysis

Interview transcripts were analysed using thematic analysis, which is a widely used qualitative analytic method used to identify and report themes related to stakeholder perspectives [32].

Moreover, a demonstration of the trace of blockchain transactions was performed to provide a preliminary evaluation in identifying Halal food towards building consumer confidence for Halal compliance. All together, these methods presented strengths and provided a background that supported the investigation of blockchain technology to improve distribute trust within Halal from broiler supply chains [33].

Fifteen industry experts in Malaysia have been interviewed with the objective of exploring the role of blockchain technology in improving Halal traceability of broiler supply chains in Malaysia, thus the interview questions are outlined as below:

The questions are organized into four sections: General Awareness, Challenges, Blockchain Potential, and Implementation Strategies. Table 1 shows is the questionnaire for the participants.

Table 1
Questionnaire for industry experts on blockchain and halal traceability

Theme	Sample Questions	Objective
General Awareness	- What is your role and involvement in the Halal broiler supply chain in Malaysia? - How familiar are you with the concept of Halal traceability? - How is Halal traceability currently implemented in your organization?	To assess the current level of knowledge and awareness regarding Halal traceability practices.
Challenges	- What are the main challenges in ensuring Halal compliance and traceability? - Have you faced fraud, mislabeling, or non-compliance issues? - How can the current traceability systems be improved?	To identify barriers, risks, and weaknesses in existing systems.
Blockchain Potential	- Are you familiar with blockchain technology? - How can blockchain enhance Halal traceability? - What potential benefits do you see for producers, regulators, and consumers?	To explore perceptions of blockchain as a solution for transparency and accountability.
Implementation Strategies	- What are the key barriers to implementing blockchain in Halal broiler supply chains? - How can stakeholders collaborate to overcome these barriers? - What role should government and certification bodies (e.g., JAKIM) play?	To evaluate strategies for blockchain adoption and stakeholder collaboration.
Future Directions	- How can blockchain be integrated with other technologies such as IoT or AI? - What recommendations would you provide for businesses adopting blockchain? - How can blockchain strengthen Malaysia's position in the global Halal industry?	To gather insights on innovation, future applications, and policy implications.

Table 2 shows the list of 15 participants from the Malaysian Halal broiler industry, including their roles, organizations, and general details. These participants represent a diverse range of stakeholders, including producers, regulators, certification bodies, and technology providers.

Table 2
List of participants

Code	Category	Role
P1	Producer	Supply Chain Manager
P2	Producer	Quality Assurance Manager
P3	Producer	Regional Manager
P4	Producer	Logistics Manager
P5	Producer	Sustainability Officer
P6	Producer	Division Manager
P7	Producer	Marketing Director
R1	Regulator	Policy Advisor
R2	Regulator	Halal Certification Officer
C1	Certification Body	Halal Auditor
C2	Certification Body	Halal Compliance Officer
T1	Technology Provider	Blockchain Developer
T2	Technology Provider	IT Specialist
T3	Technology Provider	Halal Consultant
T4	Technology Provider	Academic Researcher

3.3 Theoretical Framework

The framework of the study (Figure 1) are as follows :

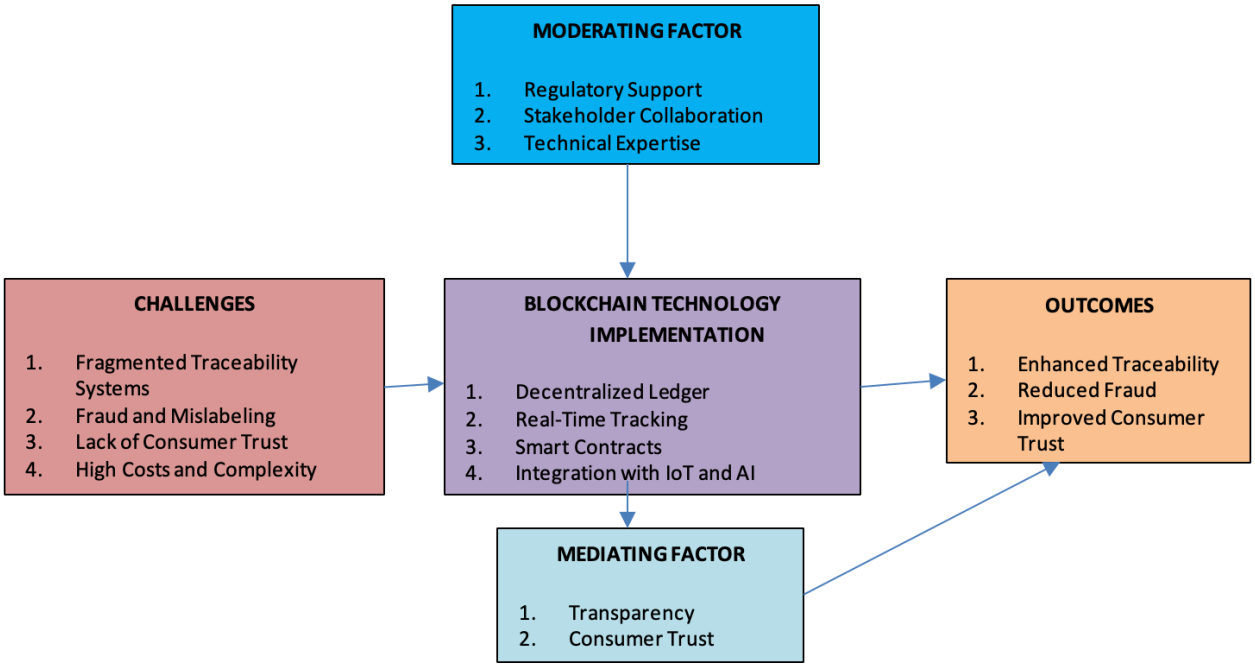

Fig. 1. Theoretical framework of halal traceability in supply chain

4. Findings

This study is based on semi-structured interviews with fifteen industry experts in Malaysia, an examination of blockchain frameworks, and data from a blockchain-based traceability system that serves as a reference for Halal broiler supply chains. The findings are grouped into three central themes: enhanced traceability, reduced fraud, and improved consumer trust. These results provide direct evidence in addressing the research problem, research questions, and objectives [34].

4.1 Enhanced Traceability

Participants consistently emphasized that blockchain enables real-time and transparent tracking of broiler products. Participant R2 explained that blockchain acts as a tamper-proof record, ensuring Shariah practices are followed from farm to packaging. P1 and P2 agreed, highlighting that product data such as chick source and feed composition can now be tracked more effectively compared to manual records. P3 and P4 added that blockchain provides live updates on storage and transportation, which reduces risks of contamination and improves logistics coordination. From a regulatory perspective, R1 noted that blockchain aligns with national Halal certification requirements, making monitoring more efficient. Participant T4 suggested that blockchain's integration with IoT could further enhance data accuracy in real time. Collectively, these responses show blockchain's potential in reinforcing supply chain integrity and Halal compliance [35].

4.2 Reduced Fraud

The issue of fraud and mislabeling was a recurring concern. Participant C1 emphasized that blockchain prevents falsification of certification records by creating an immutable ledger. C2 reinforced this point, noting that the technology eliminates opportunities for tampering with audit trails. Producers P5 and P6 observed that fraud is a common issue in the broiler sector, with cases of non-Halal feed substitution and false labeling; both argued that blockchain could significantly reduce these risks. Participant T1 provided a technical view, explaining that blockchain's decentralized nature means no single actor can alter records without detection. R1 and R2 acknowledged that fraud cases weaken consumer trust and expressed that blockchain adoption could support enforcement by certification bodies. Participant P7 also stressed the marketing advantage, as fraud prevention builds stronger brand credibility. These findings resonate with prior studies that associate blockchain adoption with decreased mislabeling in food supply chain [36].

4.3 Improved Consumer Trust

Participants agreed that consumer trust is one of the most significant benefits of blockchain. P7 explained that consumers can scan QR codes to verify Halal compliance, giving them confidence in the product. P1 and P2 stressed that this transparency helps rebuild trust after several high-profile cases of Halal fraud in Southeast Asia. R1 highlighted that blockchain strengthens the credibility of certification bodies, while C1 mentioned that consumers increasingly expect real-time verification rather than static labels. Participant T2 emphasized that providing consumers with blockchain-based data directly on their mobile devices could enhance confidence. Meanwhile, P3 and P5 argued that transparency not only builds trust but also justifies higher product prices for Halal-certified broiler products. T3, who works as a consultant, underlined that trust is not only religious but also economic,

as verified Halal products can secure greater access to export markets. Overall, these responses support the view that blockchain adoption empowers consumers and improves loyalty [37].

5. Discussion

The results of this study confirm prior literature on the value of blockchain in food traceability while highlighting unique insights from the Halal broiler supply chain in Malaysia. The findings reveal both opportunities and barriers, addressing the research problem, questions, and objectives through perspectives shared by producers, regulators, certification bodies, and technology providers.

5.1 Addressing the Research Problem

The central research problem was the lack of a reliable traceability system in Halal broiler supply chains, which leads to fraud, mislabeling, and instances of non-compliance. Input from the participants consistently indicated that blockchain can provide an immutable and transparent record of product information, reducing such risks. For example, P1 emphasized that blockchain enables the tracking of every process, from feed supply to slaughter, ensuring Halal compliance at each stage. R1 explained that the technology provides regulators with a verifiable record of audits, reducing the possibility of oversight. Similarly, C1 highlighted that certification records stored on blockchain cannot be falsified. T2 added that by integrating blockchain with IoT, data collection becomes more reliable, allowing continuous verification. These findings demonstrate that blockchain directly addresses the core traceability challenges [38].

5.2 Answering the Research Questions

5.2.1 RQ1. How can blockchain technology enhance traceability in Halal broiler supply chains?

The participants confirmed that blockchain enhances traceability by enabling real-time verification of product information. P2 noted that blockchain minimizes human errors by removing dependence on manual records. P3 described how data on storage conditions and transportation are automatically captured, ensuring product integrity. R2 stressed that decentralization reduces intermediaries and prevents manipulation. T3 stated that blockchain integration creates efficiency in monitoring systems, aligning with prior studies [39].

5.2.2 RQ2. What are the challenges and opportunities of implementing blockchain for Halal traceability?

Several participants pointed out challenges. P4 and P6 raised concerns about high initial investment, especially for SMEs with limited resources. T1 explained that technical barriers, such as lack of skilled professionals, hinder adoption. However, participants also emphasized the opportunities. P7 noted that blockchain enhances the credibility of Halal certification, while C2 mentioned that it fosters stronger trust between businesses and consumers. R3 stated that blockchain improves regulatory oversight, and T4 added that long-term cost savings and risk reduction justify the initial investment. These responses reflect prior evidence that although blockchain implementation is costly, its long-term benefits are substantial [31][32].

5.2.3 RQ3. How does blockchain improve consumer trust in Halal broiler products?

Consumer trust emerged as one of the strongest benefits. P5 stated that consumers feel reassured when they can verify Halal status via QR codes. P7 emphasized that transparency directly increases willingness to pay for certified products. C1 and C3 explained that blockchain enables real-time verification by consumers, which traditional systems cannot provide. R1 and R2 both agreed that transparent certification records increase confidence in the Halal label. T2 added that blockchain-based traceability allows exporters to access international markets where Halal assurance is strictly evaluated. This is consistent with prior findings that transparency and immutability improve trust and confidence among Muslim consumers [33,34].

5.3 Meeting the Research Objectives

5.3.1 RO1. To explore the potential of blockchain technology in enhancing Halal traceability

The study showed that blockchain offers a secure ledger that ensures transparency and reliability across the value chain. P1 to P3 confirmed that the technology allows verification at each stage of the supply chain. T3 and T4 elaborated that when combined with IoT and AI, blockchain becomes even more effective. These results echo earlier research that found blockchain improves food traceability systems [35].

5.3.2 RO2. To identify the challenges and opportunities of blockchain adoption in broiler supply chains

Participants highlighted financial and technical barriers. P4 and P6 noted the difficulty SMEs face in investing in infrastructure and training. T1 highlighted the lack of expertise as another obstacle. At the same time, opportunities were recognized. C2 described how blockchain enhances ethical practices through transparency. P7 explained that blockchain supports sustainable broiler production by ensuring compliance with Halal standards. R3 emphasized that blockchain strengthens food safety monitoring. These insights support evidence that blockchain simultaneously poses implementation challenges and enables sustainability benefits [36].

5.3.3 RO3. To assess the impact of blockchain on consumer trust and compliance with Halal standards

The findings revealed that blockchain positively impacts both consumer trust and compliance. P5 and P7 reported that transparency improves repeat purchase intentions. C1 explained that blockchain ensures Halal standards are continuously met, and T2 noted that consumers appreciate having accessible proof of Halal integrity. R2 confirmed that compliance is more easily monitored by regulators. These responses align with studies that link blockchain to enhanced consumer confidence and higher levels of compliance [37][38].

6. Conclusion and Recommendation

Blockchain technology presents a transformative solution for enhancing Halal traceability in broiler supply chains by enabling secure and verifiable record-keeping that reduces fraud, prevents mislabeling, and strengthens consumer trust. The findings of this study position blockchain as a critical innovation for the Halal food industry, warranting further exploration into its adoption and integration with other digital technologies. Based on the research, this section provides actionable recommendations for consumers, producers, regulators, certification bodies, and policymakers to

harness blockchain's potential in improving traceability, compliance, and trust in Halal broiler supply chains.

6.1 Industry Adoption of Blockchain Technology

The study highlights blockchain's potential to significantly enhance traceability and compliance in Halal broiler supply chains. To capitalize on this, industry players including producers, processors, and distributors should invest in blockchain-powered traceability systems that securely track critical data such as chicken origin, feed ingredients, slaughtering methods, and transportation processes. Pilot projects should be launched within selected supply chains to assess effectiveness and build stakeholder confidence, while technical training and support must be provided to ensure smooth adoption. For instance, participants P01, P04, and P07 emphasized that blockchain enables real-time monitoring of product location, storage conditions, and production methods, ensuring Halal integrity throughout the process. This aligns with previous findings that blockchain ensures transparency and integrity in food systems [4].

6.2 Support from Regulatory and Standardization Agencies

For blockchain to be viable in Halal broiler supply chains, strong regulatory backing and standardization are essential. Governments and Halal certification bodies such as Malaysia's Department of Islamic Development (JAKIM) should establish guidelines for blockchain-based traceability systems, covering technical requirements, data formats, and compliance criteria. A regulatory framework must be developed to guide blockchain implementation, while standardized protocols should ensure interoperability between different supply chain networks. Financial incentives, such as grants or subsidies, should also be offered to small and medium enterprises (SMEs) to facilitate adoption. Participants P02, P05, P08, and P12 highlighted that regulatory support is crucial in overcoming blockchain adoption challenges, particularly for SMEs with limited resources. This view is reinforced by the Halal Assurance Management System (HAS 23000) and Malaysian Halal Certification Procedure, which emphasize blockchain's role in ensuring end-to-end visibility.

6.3 Consumer Education and Awareness

Consumer trust is vital for the success of Halal broiler products, and blockchain can provide authentic and verifiable data to reassure consumers about Halal compliance. Industry stakeholders should implement QR codes or mobile applications to allow consumers to verify a product's Halal status via blockchain, while awareness campaigns should educate them on blockchain's benefits for transparency. Collaboration with Halal certification bodies and consumer organizations can further promote blockchain's role in ensuring authenticity. Participants P03, P06, P10, and P13 noted that QR code verification directly addresses authenticity concerns by allowing consumers to scan and confirm Halal status. These findings support research showing that blockchain strengthens consumer confidence in food systems [30].

6.4 Integration with Emerging Technologies

Combining blockchain with technologies such as the Internet of Things (IoT) and artificial intelligence (AI) can further enhance Halal traceability. Industry players should integrate IoT devices to collect real-time production and processing data, which can then be stored on blockchain for

accountability. AI algorithms should be developed to analyze blockchain data, identifying potential risks or Halal compliance issues. Partnerships with technology providers and research institutions can explore blockchain–IoT–AI synergies. Participants P09, P11, and P14 stressed that the interoperability of blockchain with IoT sensors for temperature monitoring and AI-based predictive analytics is essential for improving Halal assurance. This is consistent with studies showing that blockchain combined with IoT provides stronger guarantees for food safety and traceability [31].

6.5 Removing Barriers to Adoption

High costs, lack of technical expertise, and resistance to change remain significant barriers to blockchain adoption in Halal broiler supply chains. Stakeholders must introduce financial incentives, such as subsidies, to help SMEs cover initial costs, while training programs and workshops should build technical knowledge among employees. A collaborative culture should also be fostered to reduce resistance to technological change. Participants P12, P13, and P15 acknowledged that while the initial costs and technical barriers exist, the long-term benefits including reduced fraud and increased consumer trust justify the investment. This perspective is supported by earlier research which found that blockchain adoption in food systems requires both financial support and technical training to succeed [32].

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