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Digital Technology Based Halal Certification Model in Nigeria: Exploring the Potential of Blockchain for Transparency and Anti-Fraud Measures

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Abstract
The halal certification system in Nigeria currently faces serious challenges, including weak transparency, vulnerability to document falsification, and limited supply-chain oversight, whereas ideally halal certification should ensure authenticity, accountability, and public trust throughout the entire value chain. This study aims to develop a conceptual model of digital halal certification that aligns with Nigeria's social, economic, and regulatory context. The research employs a qualitative approach through a literature review by examining Nigerian halal policies, institutional reports, and recent scholarly publications on blockchain and halal management; the data were then analyzed using content analysis supported by theoretical triangulation. The findings indicate that blockchain has significant potential to enhance transparency, tracking accuracy, and fraud prevention within Nigeria's halal ecosystem, although its implementation requires regulatory readiness, technical capacity, and stakeholder collaboration. The study recommends the development of a context-appropriate blockchain architecture for halal certification, the implementation of pilot projects to assess technical effectiveness, and the formulation of policy frameworks that support long-term adoption of this technology in the national halal certification system.

Keywords: Halal Certification, Blockchain, Transparency

Abstrak
Sistem sertifikasi halal di Nigeria saat ini menghadapi tantangan serius, termasuk lemahnya transparansi, kerentanan terhadap pemalsuan dokumen, dan

keterbatasan pengawasan rantai pasok, padahal idealnya sertifikasi halal harus menjamin keaslian, akuntabilitas, dan kepercayaan publik di seluruh rantai nilai. Penelitian ini bertujuan untuk mengembangkan model konseptual sertifikasi halal digital yang sesuai dengan konteks sosial, ekonomi, dan regulasi di Nigeria. Penelitian ini menggunakan pendekatan kualitatif melalui studi literatur dengan menelaah kebijakan halal Nigeria, laporan kelembagaan, serta publikasi ilmiah terbaru mengenai blockchain dan manajemen halal; data kemudian dianalisis menggunakan analisis isi yang didukung oleh triangulasi teori. Hasil penelitian menunjukkan bahwa blockchain memiliki potensi besar untuk meningkatkan transparansi, akurasi pelacakan, dan pencegahan kecurangan dalam ekosistem halal Nigeria, meskipun implementasinya memerlukan kesiapan regulasi, kapasitas teknis, dan kolaborasi para pemangku kepentingan. Penelitian ini merekomendasikan pengembangan arsitektur blockchain yang sesuai dengan konteks sertifikasi halal, pelaksanaan proyek percontohan untuk menguji efektivitas teknis, serta penyusunan kerangka kebijakan yang mendukung adopsi jangka panjang teknologi ini dalam sistem sertifikasi halal nasional.

Kata Kunci: *Sertifikasi Halal, Blockchain, Transparansi*

INTRODUCTION

In recent years, the demand for halal products in Nigeria has risen significantly, driven by the growth of the Muslim middle class and the expansion of the modern food market. However, this increase has been accompanied by serious challenges, including the widespread adulteration of meat and the presence of actors who exploit regulatory gaps to introduce unsafe products into the market (Adenuga & Montowska, 2023). Such conditions have generated public doubt regarding the credibility of existing halal certificates, particularly as consumers have become increasingly sensitive to issues of safety and product authenticity (Aslan, 2023). This situation reflects a widening gap between consumer expectations and the actual capacity of the current halal system.

The problem is further compounded by the absence of a unified national halal authority in Nigeria. Each certification body operates with its own guidelines and verification mechanisms, making it difficult to compare and collectively monitor certification standards (Ademola et al., 2024). This fragmentation contributes to weak transparency across the supply chain, especially in the meat sector, which involves numerous distribution points. As a result, stakeholders struggle to ensure that products circulating in the market have undergone a consistent and accountable halal process.

This condition demonstrates that the conventional halal system has fundamental limitations in detecting fraud. The dominance of manual audits means that tracing the origin of raw materials is not always accurate, while paper-based documentation remains vulnerable to manipulation (Razak et al.,

2023; Van Asselt et al., 2021; Ulberth, 2020). In meat and processed products, these gaps enable adulteration practices that are not easily identified. This highlights that although halal demand is rising, the system's ability to guarantee integrity lags significantly behind market needs.

Existing studies on halal certification in Africa largely focus on social dynamics, institutional aspects, and consumer compliance, yet they seldom address digital trust as a foundation for modern halal governance (Fauzi et al., 2024; Ghazali et al., 2022; Bashir, 2019). These studies do not sufficiently integrate discussions on how decentralized systems could structurally strengthen the validity of halal information. Consequently, technological solutions remain at a conceptual level and lack robust theoretical support needed for transforming halal certification systems.

This gap becomes more evident considering the limited number of comprehensive studies exploring the integration of blockchain technology within the context of Nigeria's halal ecosystem. Existing research mainly addresses consumer perception, market dynamics, or institutional arrangements but rarely touches on the technical and system-design dimensions required to achieve end-to-end transparency (Olodo & Aremu, 2025; Abdullahi, 2024; Adebayo & Salaudeen, 2021). The absence of such multidisciplinary inquiry hinders the development of a contextualized digital halal model, despite the urgent need for more reliable audit mechanisms amid the rapid expansion of the national halal market.

The urgency of reforming Nigeria's halal system becomes clearer when viewed alongside global trends in the halal industry, which increasingly demand consistent standards and credible verification processes. Major exporting countries have strengthened technology-based oversight mechanisms, urging Nigeria to upgrade its system to remain competitive (Duan et al., 2024; Wang et al., 2024). Moreover, domestic consumers expect higher transparency regarding the products they consume, driven by concerns over health and ethical food practices (Nordhagen, 2022; Onyeaka et al., 2024). These internal and external pressures render halal system reform a strategic necessity rather than an optional initiative.

Based on these conditions, the core problem of this study lies in examining how blockchain technology can support the development of a transparent, integrated, and fraud-resistant halal certification system. The challenge is to formulate mechanisms that ensure halal-related data cannot be altered and remain verifiable by all supply-chain actors. The study must also assess how blockchain structures can address weaknesses in manual verification, which currently represent the most vulnerable point in the Nigerian halal system.

This study aims to develop a conceptual model for digital technology–based halal certification tailored to Nigeria's social, economic, and regulatory context. The model is expected to outline the relevant actors, audit flows, and verification mechanisms that allow halal information to be permanently

recorded and easily traced. By designing a contextual framework, this research seeks to bridge the need for modernization with on-the-ground realities, ensuring that the proposed solution is not merely theoretical but practically applicable.

To achieve these objectives, the study adopts a literature-based approach by reviewing international publications on digital technologies, Nigerian government policy documents, and relevant reports from the halal industry. This approach enables a comprehensive understanding of the operational challenges, regulatory environment, and technological readiness that influence the implementation of a digital halal system. By mapping insights from diverse sources, the analysis generates a more robust foundation for formulating the proposed halal certification model.

The contribution of this research is both theoretical and practical. Theoretically, it offers a new framework for digital halal certification that integrates the concept of digital trust with the governance needs of halal systems. Practically, it provides recommendations for regulators, certification bodies, and industry actors to build a halal system that is more transparent and accountable. Thus, this study is expected to serve as an initial reference in designing modern, technology-based halal policies and systems for Nigeria.

Research on halal certification has been widely explored in various studies. Generally, these works discuss halal governance from the perspectives of industry compliance, consumer psychology, and challenges in sourcing halal raw materials. Abdul Halim et al., (2024) for example, highlight multiple non-conformance reports (NCRs) among halal-certified SMEs in Malaysia, largely rooted in low halal awareness, weak managerial commitment, and bureaucratic constraints. Meanwhile, Aslan (2023) focuses on factors influencing consumers' intentions to purchase halal products in Türkiye, such as religiosity, subjective norms, halal awareness, and the strong influence of halal certification on consumer trust. In another study, Herdiana et al., (2024) examine challenges in ensuring halal raw materials in the pharmaceutical sector, emphasizing the importance of non-porcine alternatives from poultry, marine sources, and plants, alongside the need to improve halal awareness, producer compliance, and government support.

Although these studies provide valuable insights, they remain concentrated on conventional aspects of halal governance—procedural compliance, consumer attitudes, and raw material challenges. None of them examine how digital technologies, particularly blockchain, could enhance certification transparency, accountability, and fraud prevention. This research addresses this gap by exploring a digital technology–based halal certification model for Nigeria and assessing the potential of blockchain to strengthen trust, traceability, and the overall integrity of halal certification processes.

RESEARCH METHOD

This study employs a qualitative approach based on literature analysis, focusing on academic documents, institutional reports, and official publications related to halal certification in Nigeria as well as the development of blockchain technology in the food sector. The data sources consist of international journal articles, Nigerian government regulations, and publications from global organizations concerning supply chain technologies. This literature-based approach allows the researcher to examine structural patterns, systemic issues, and opportunities for digital innovation without conducting field data collection. Sources were selected purposively by considering relevance, academic credibility, and contextual alignment with the research objectives.

Data were analyzed using thematic content analysis by extracting key themes from various publications, which were then synthesized into a comprehensive conceptual framework. The validity of the findings was strengthened through cross-literature verification, which involves comparing the consistency of information across articles, reports, and policy documents to ensure accuracy and reduce interpretive bias. This procedure helps identify knowledge gaps and supports the formulation of a digital halal certification model relevant to Nigeria's socio-economic conditions and governance structures. The results are presented argumentatively by highlighting the relationship between the challenges of the halal certification system and the potential application of blockchain technology as a solution for enhancing transparency and preventing fraud.

DISCUSSION

Halal Certification in Nigeria: Structure, Challenges, and Dynamics

Halal certification in Nigeria began to grow significantly in the mid-2010s with the emergence of the Halal Certification Authority (HCA) as one of the most active private bodies responsible for verifying the halal compliance of local products (Ademola et al., 2024). HCA plays a crucial role in bridging the needs of Nigeria's expanding Muslim consumer base with a certification system that lacks strong government regulation. Its establishment marked a new phase in Nigeria's modern halal institutional landscape, where halal audits started to be organized more professionally and publicly recognized as credible certification efforts.

Within the institutional structure, HCA operates as the main non-governmental certification body, while NAFDAC oversees food safety and product distribution, and SON sets technical product standards in Nigeria (Onyeaka et al., 2021; Sani et al., 2022). Together, these institutions form a system in which HCA conducts the shariah verification, whereas NAFDAC and SON provide the broader regulatory framework. Their roles complement one another: HCA focuses on halal auditing, while NAFDAC and SON ensure product quality and safety.

Despite HCA's rise as a leading player, fragmentation persists due to the absence of a single national authority that coordinates halal certification bodies. Many halal certificates in Nigeria are issued by various independent organizations (Muhammad et al., 2025). Such diversity has resulted in inconsistencies in audit requirements, field inspections, and document verification across certification bodies, ultimately reducing cross-industry and consumer trust.

The lack of uniform audit procedures significantly affects the consistency of certification outcomes. Since each organization applies different methodologies, audit results may vary widely, triggering public debate about the reliability of halal certificates. Without a unified national standard, these interpretive differences hinder efforts to ensure that certified production processes genuinely comply with both shariah principles and technical standards.

HCA also faces challenges related to physical verification infrastructure. Although it conducts audits and laboratory testing, independent analytical facilities in Nigeria remain limited, resulting in suboptimal testing for contamination or prohibited substances. Meanwhile, NAFDAC and SON have yet to fully provide standardized facilities for halal analysis, weakening the technical verification instruments within the certification system (Bamidele, 2025; Ojo-Solomon, 2022).

Nigeria's meat supply chain is highly complex and informal, ranging from local slaughterhouses to traditional and modern markets. As a halal certification body, HCA must contend with the reality that many supply chain points are poorly documented. Without reliable traceability records, verifying the halal status of raw materials becomes difficult and prone to irregularities. This complexity complicates HCA's efforts to guarantee product halal integrity until the point of consumption.

Logistical and sanitation issues further exacerbate structural challenges. Many meat and livestock products are transported using conventional vehicles that may not meet hygiene standards, and cold storage facilities remain limited. As a result, HCA faces significant difficulties in ensuring that halal-certified products maintain their integrity throughout the distribution chain. The combination of informal supply systems and weak sanitary controls highlights the need for stricter and more professional monitoring mechanisms.

Economically, Nigeria's halal industry shows significant potential due to its large Muslim population and growing demand for halal products (Muhammad et al., 2025). HCA has secured a substantial market share, accrediting more than 100 companies and 300 products in recent years (Gbenga, 2025). However, certification costs and uncertainty regarding compliance remain barriers for small and medium enterprises, while consumers still consider price and accessibility when choosing certified halal products.

Beyond economic factors, socio-cultural dynamics also influence HCA's legitimacy. Many Muslim consumers continue to rely on the reputation of local

traders or mosques as indicators of halal authenticity, rather than formal certificates. This perception stems from limited literacy regarding the value of certification and the audit processes conducted by HCA. Community interaction with halal auditors and greater transparency in the audit process are essential for improving public acceptance, particularly among traditional market stakeholders.

Halal fraud cases in Nigeria also pose reputational challenges for HCA. Practices such as meat adulteration, the mixing of non-halal ingredients, and counterfeit halal labels are reported periodically (Njiru et al., 2025). With multiple certification bodies operating and minimal centralized regulation, monitoring becomes increasingly difficult. This highlights the need for HCA to strengthen field verification, audit rigor, and collaboration with regulators like NAFDAC and SON to ensure the integrity of halal-certified products.

A major challenge remains the lack of traceability mechanisms. HCA can only audit certain stages of production; without proper documentation from farmers to distributors, verifying the authenticity of input materials becomes difficult (Onyeaka et al., 2024). Nigeria's production system has not yet universally adopted formal traceability frameworks, causing audits to rely heavily on factory statements or documentary reports, which may not accurately reflect actual conditions.

Coordination between HCA and national regulators such as NAFDAC and SON remains loose and ad hoc. Although some memoranda of understanding have been reported, regulatory collaboration is not implemented uniformly across states. Differences in institutional mandates and priorities—HCA focusing on halal compliance while NAFDAC and SON prioritize quality and safety—create gaps in oversight and accountability.

Digital technology use in HCA's certification process remains limited. Most audits rely on manual documentation and physical inspections. HCA has not yet fully integrated digital systems for real-time tracking, reporting, and halal monitoring. This limitation slows response times to potential fraud and constrains the level of transparency and accountability that modern technology could offer.

HCA plays a central role in Nigeria's halal certification sector; however, the current system still faces multiple constraints. Heavy reliance on manual audits, the absence of unified national standards, and limited technical infrastructure undermine the credibility of certification outcomes. To enhance public trust and strengthen accountability, a more systematic and transparent approach is needed. A digital certification model, supported by collaboration between HCA, NAFDAC, and SON, can reinforce verification mechanisms, ensure traceability of raw materials, and improve the overall integrity of Nigeria's halal supply chain.

Blockchain: Principles, Auditability, and Relevance for the Halal System

Blockchain is essentially a digital recording system distributed across numerous nodes, eliminating dependence on a single central server (Tripathi et al., 2023). Each transaction or new piece of data is stored in a block that is chronologically linked to the previous one, forming a chain that is extremely difficult to alter. This distributed structure makes blockchain resistant to manipulation, as any change to one node must be approved by the network as a whole (Anthony Jnr, 2023). Such principles provide a technological foundation suitable for systems requiring a high level of trust, including halal certification processes that demand data integrity and tamper-proof documentation trails.

The basic structure of blockchain consists of blocks that store data, the block's hash, and the hash of the previous block. A hash functions as a unique digital fingerprint, which means that even the slightest change to the data will produce an entirely new hash, rendering it inconsistent with the previous chain (Bamakan et al., 2020). The multi-layer verification process conducted by the network ensures that each new block is valid before it is accepted into the chain (Hussein et al., 2023). This mechanism reinforces the integrity of each record, making blockchain highly suitable for documenting halal processes that require assurance that every production step is recorded authentically without hidden modifications.

Trust in blockchain is built through consensus mechanisms—procedures used to determine whether new data is eligible to be added to the network without relying on a central authority. Consensus can take the form of proof-of-work, proof-of-stake, or other models that ensure nodes collectively agree on the validity of a transaction. With this structure, blockchain removes the need for a single institution to act as the ultimate authority of truth (Ahn et al., 2024). In the context of halal oversight, this principle opens opportunities for a more collective and transparent system in which verification can be automated through an agreed-upon network.

One of the most fundamental features of blockchain is immutability—the inability to alter data once it has been recorded. Immutability ensures that every record is final and protected from both intentional and unintentional manipulation (Hariyani et al., 2025). In halal certification, this characteristic is crucial because data regarding raw material origins, production processes, and audit results must maintain their integrity. With blockchain, any attempt to modify audit outcomes or alter halal documents after issuance can be instantly detected. This provides a much stronger safeguard compared to conventional digital recording methods.

Smart contracts are another critical component within the blockchain ecosystem, enabling automated rule enforcement without human intervention (Zheng et al., 2020). In the halal context, smart contracts can be programmed to enforce halal requirements—such as confirming that suppliers are registered, verifying ingredient status, or triggering digital alerts when procedural violations

occur. These rules execute automatically once predefined conditions are met. Thus, smart contracts not only accelerate halal verification processes but also reduce administrative errors commonly found in manual certification models.

Integrating blockchain with Internet of Things (IoT) devices enables real-time monitoring of product conditions throughout the supply chain. Sensors can record temperature, location, or transportation conditions and transmit the data to the blockchain, where it becomes immutable (Z. Liu et al., 2025). For halal products, this capability is highly relevant to ensuring that handling, storage, and distribution procedures comply with required standards. When each point in the supply chain is automatically and accurately recorded, halal audits become more objective and based on real-time data rather than solely on producer reports.

Blockchain enhances the accountability of certification bodies through transparent and permanently stored records accessible to authorized stakeholders. By documenting all audit processes digitally and immutably, certification agencies cannot conceal errors or modify data after a certificate is issued (Kumar et al., 2025). This transparency drives higher professional standards among auditors because all actions are traceable and verifiable at any time. In countries facing regulatory challenges in halal oversight, blockchain acts as a supervisory tool ensuring that certification bodies uphold principles of integrity and professionalism.

One of the common issues in halal products is label fraud, whether through package substitution or the use of counterfeit certificates. Blockchain provides a solution by assigning each halal certificate a unique identifier linked to an immutable audit record. Consumers, distributors, or government authorities can simply scan the code to verify authenticity. This effectively closes the administrative loopholes typically exploited in fraud cases. Consequently, blockchain strengthens consumer confidence and improves overall market integrity.

The distributed ledger concept in blockchain makes it highly suitable for the halal industry, which involves multiple stakeholders—from farmers, producers, laboratories, and auditors to certification bodies (Adhiwibowo et al., 2025). Shared records ensure that all stakeholders base their decisions on identical information. No party can monopolize or alter the data unilaterally, minimizing the risk of conflicting information. This model supports a more cooperative halal ecosystem and ensures full transparency across all stages of production.

Compared with traditional halal supervision models that rely on frequent inspections and manual verification, blockchain offers significant potential for reducing operational costs (Duan et al., 2023). Automated verification through smart contracts and real-time tracking reduces the need for extensive physical audits, which often require significant time, manpower, and logistics. Additionally, decreasing document manipulation reduces litigation costs and product recalls resulting from non-compliance. Thus, blockchain helps

governments, certification bodies, and industries implement more efficient halal oversight without sacrificing quality.

In the food sector, blockchain has distinct advantages in addressing fraud such as meat adulteration or substitution with prohibited ingredients. By recording the origin of every ingredient in detail and linking it to tamper-proof verification processes, blockchain narrows opportunities for dishonest practices. When each production stage is timestamped and verified by the network, identifying violations becomes far easier. This allows enforcement actions and corrective measures to be taken promptly and based on digital evidence (Patel et al., 2023).

Global traceability standards emphasize the importance of tracking products from origin to end-consumer. Blockchain aligns strongly with these standards, allowing comprehensive traceability without the risk of data loss. The halal industry, which requires certainty regarding product origin and processing methods, can benefit greatly from this system (Harsanto et al., 2024). With blockchain, traceability extends beyond formal documentation to include physical condition records through IoT. This makes compliance with international standards more achievable and consistent.

Many countries have experimented with using blockchain within the food industry, offering valuable insights for developing halal systems. In Australia, for example, several meat producers use blockchain to track products from farms to supermarkets (Cao et al., 2022). Meanwhile, South Korea employs similar technologies to ensure food safety (Jang et al., 2024). These examples demonstrate blockchain's ability to enhance supply chain integrity, providing a strong theoretical basis for its effective use in Nigeria's complex halal certification environment.

For consumers, blockchain enables broader and more accessible information regarding product halal status. Instead of relying solely on static labels, consumers can access detailed production process data through applications or unique code scans. This transparency strengthens public trust and reduces the information asymmetry that often leads to doubts regarding product authenticity. Thus, blockchain fosters a healthier relationship between consumers and producers within the halal ecosystem.

The characteristics of blockchain—from data integrity and automated rule enforcement to multi-stakeholder transparency—align strongly with the needs of Nigeria's halal certification system, which faces issues of accountability and traceability. This technology offers a framework capable of addressing structural weaknesses that manual mechanisms struggle to resolve. With proper integration, blockchain can support a more credible, standardized, and market-responsive halal certification system. Therefore, its adoption represents a strategic step toward strengthening the foundation of halal certification in Nigeria.

Digital Halal Certification Model for Nigeria: Structure, Actors, and Processes

The digital halal certification model for Nigeria requires a structure that includes core components such as a blockchain platform, certificate management modules, supply chain tracking systems, supporting sensor networks, and a public verification interface. All these elements must be designed to establish an integrated workflow among certification bodies, the government, industry actors, and consumers. The model should also consider local dynamics related to technological availability, variations in industrial scale, and the need for automated audit mechanisms without compromising accuracy. This initial framework serves as a conceptual foundation for building a comprehensive digital halal system.

In this model, the national halal authority acts as the primary administrator node responsible for managing data recording and validation processes. This position is crucial because the halal authority holds the highest mandate in determining the halal status of products. By managing the main node, the authority can ensure that every digital transaction follows audit procedures and established halal standards. This role also strengthens accountability because final decisions regarding product eligibility are permanently recorded on the network, reducing manipulation risks commonly found in conventional systems.

The government functions as the regulator that establishes the legal framework to support the operation of the digital halal system. Such regulations include technology standards, requirements for industries to upload process data, sanction mechanisms for violations, and rules concerning interoperability with national food safety systems. Additionally, the government may provide incentives to accelerate technology adoption among small and medium-sized enterprises. By creating a clear legal environment, the government ensures that the digital platform operates effectively and is accepted by all stakeholders without causing jurisdictional conflicts.

Industry actors serve as the primary contributors responsible for regularly inputting production, distribution, and processing data into the system (Jahanbin et al., 2023). They must document each stage, from raw material selection to processing and final distribution. The accuracy of this data determines the overall success of the digital model because blockchain relies on the integrity of initial inputs. Thus, industries must receive training to operate the platform and comply with established data governance standards. This role ensures that the digital system does not merely record information but genuinely reflects actual production conditions.

Auditors maintain a central role as the parties responsible for verifying the authenticity of field data. Through the digital platform, auditors can compare digital records with physical conditions observed during inspections (Lei et al., 2022). Their involvement ensures that verification does not rely solely on automated data but also incorporates necessary professional judgment for assessing the complexities of halal processes. Because all inspection activities

are recorded in the system, auditors work within a transparent environment that protects them from potential external interference, thus significantly improving audit quality.

The halal product registration flow in this digital model begins when a company submits an application through the platform. The system then generates a unique digital identity for the product. After initial documents and data are verified, auditors conduct field validation. If all requirements are met, the halal authority issues a digital certificate linked directly to blockchain records. This certificate number is unique and cannot be duplicated, enabling efficient public tracking and verification. The digital process shortens certification timelines without reducing inspection rigor.

Smart contracts play a key role in automatically monitoring production stages. These digital contracts can be programmed to verify whether specific conditions are met before a product proceeds to the next stage (Y. Liu et al., 2024). For example, the system may block validation if raw materials have not been verified or if sensors detect non-compliant values. This mechanism reduces reliance on manual checks and accelerates certification workflows. Smart contracts also establish an autonomous, objective monitoring system that minimizes administrative errors.

IoT integration enables real-time tracking of physical product conditions throughout the supply chain. Sensors can record storage temperature, transportation location, transit times, or container conditions, and send the data to the platform (Z. Liu et al., 2025). For halal products, such monitoring ensures that handling procedures remain compliant with halal preservation standards. When IoT data is automatically recorded on the blockchain, any deviation can be detected promptly (Kumar et al., 2025). Thus, this integration supports an evidence-based system that reduces inconsistencies between administrative records and real-world conditions.

The digital system allows consumers to access reporting and traceability features through a public interface. By scanning a designated code, consumers can view production records, auditor verifications, and supply chain information (Le, 2024). This open access strengthens public trust in halal products because the information is presented without lengthy manual procedures. Producers may also use this feature as a marketing tool, as high transparency creates added value in the market. Accordingly, the digital tracking system benefits both consumers and producers.

External audits become more credible within the digital system because every activity trail is permanently recorded. External auditors can trace information without relying on physical documents that are vulnerable to manipulation (Lei et al., 2022). With structured data, the audit process becomes more efficient and objective. Furthermore, auditors can identify systemic patterns or high-risk areas through digital data analysis. The presence of technology-verified external audits enhances accountability and reinforces the halal authority's position as an institution open to independent evaluation.

To operationalize this model, Nigeria requires digital infrastructure that includes stable internet networks, secure data centers, and the technical capacity of the halal authority to manage the blockchain platform. Human resource capacity must also be strengthened through technical training and the development of new standard operating procedures. Without adequate infrastructure and competencies, the digital system may function suboptimally or remain underutilized by industry actors. Therefore, capacity development must be an integral part of the model, not merely a technical addition.

Challenges in implementing this model include high initial costs, varied levels of digital literacy, and evolving legal readiness. Small industries may face technological investment constraints, while some auditors may need time to adapt to the new system. Moreover, the legal framework must be updated to recognize digital certificates as legally valid documents. These challenges do not diminish the model's potential but require a gradual and inclusive implementation strategy to ensure that digital transformation does not marginalize certain stakeholders.

By considering the structure, actors, and workflows that integrate both manual and digital verification, this model offers an adaptive solution suited to Nigeria's context. Digital technology presents opportunities to improve halal certification processes that have traditionally been complex, inconsistent, and vulnerable to manipulation. Once all stakeholders have clearly defined roles and supporting systems are fully established, the model has the potential to become a reliable framework for strengthening public trust and enhancing the national halal industry. Therefore, the digital halal model represents a strategic pathway toward more modern and integrity-driven halal governance in Nigeria.

Implications and Implementation Strategies for Blockchain in Nigeria's Halal Certification System

The adoption of blockchain in halal certification provides significant advantages for Nigeria's halal authority, as the technology offers automated, traceable, and tamper-resistant record-keeping mechanisms. This digital system enables highly accurate verification of production processes without relying on manual procedures that have traditionally hindered efficiency. Furthermore, blockchain strengthens the integrity of certification because all information entered into the network is validated by multiple nodes, thereby minimizing the risk of document falsification. The halal authority can enhance its credibility among both industry stakeholders and global consumers more consistently.

For industry actors, the use of blockchain in halal certification offers benefits in the form of streamlined reporting and documentation processes. The digital system enables producers to upload data regularly without going through multi-layered bureaucratic procedures common in traditional mechanisms (Karyani et al., 2024). The automation of information flows also reduces the potential for administrative errors, thereby accelerating the certification

process. Moreover, industries can present their production records more transparently to international trade partners. This enhances the competitiveness of Nigerian companies in meeting market demands for full traceability.

From a consumer perspective, blockchain integration provides stronger food safety assurance, as the entire production process can be openly traced. Information regarding raw material sources, processing facilities, and final distribution can be accessed through a digital code on the product. This transparency not only improves perceptions of halal integrity but also strengthens public trust in the institutions issuing the certification. Clear visibility of production flows helps consumers make more informed decisions, especially amid rising concerns regarding label fraud and food counterfeiting.

Digital transformation through blockchain opens substantial economic opportunities for Nigeria to expand its access to the trillion-dollar global halal market. As Muslim-majority countries play key roles in international supply chains, the demand for halal-certified products continues to grow. If Nigeria succeeds in building a credible digital system, exports of processed foods, meat, cosmetics, and pharmaceuticals will gain significant added value. The advantages of traceability assurance and document integrity provide a crucial competitive edge for Nigeria to position itself as a regional player in the halal sector.

Beyond global opportunities, blockchain has the potential to strengthen Nigeria's integration into regional African trade, which is increasingly driven by cross-country economic cooperation. A digital halal system allows cross-border verification to be carried out more efficiently because records stored in the network can be exchanged without administrative hurdles. Nigerian products can enter West African markets more easily as these markets tighten food quality standards. This integration also encourages the harmonization of halal certification across countries, thereby facilitating smoother trade flows.

Collaboration opportunities between universities, technology startups, and regulatory bodies represent a strategic component of digital halal system development. Universities can contribute technical research and prototype testing, while startups provide practical solutions that can be directly implemented. Regulators, on the other hand, play a role in formulating guidelines that ensure innovation aligns with halal certification standards. This tripartite collaboration creates a more dynamic innovation ecosystem and ensures that technological advancements remain grounded in halal requirements.

However, blockchain implementation still faces technical risks, including cybersecurity threats targeting supporting components such as servers, sensors, or user applications. Although blockchain architecture itself is robust, vulnerabilities often arise in external elements that are not adequately protected. Additionally, system failures may disrupt tracking processes if digital infrastructure is unstable. Comprehensive mitigation strategies are therefore

required, including enhanced network security, regular security audits, and continuous system maintenance (Alamri et al., 2023).

Social risks must also be considered, particularly resistance from industry actors who perceive technological change as an additional operational burden. Many small and medium-scale producers are not accustomed to digital systems and thus view blockchain implementation as a threat to established working practices. Concerns over equipment and training costs further reinforce this resistance. Persuasive approaches and structured technical assistance programs are needed to ensure inclusive technology adoption.

Regulatory barriers are a critical issue, as establishing digital-based halal certification standards requires a clear legal framework aligned with national policies. Traditional regulations that rely heavily on physical documentation must be updated to grant digital certificates the same legal recognition. Additionally, data protection regulations must be strengthened to prevent misuse of sensitive information. Without regulatory reform, blockchain adoption will be limited and unable to achieve full legitimacy.

Another major challenge lies in financing, as building digital infrastructure requires substantial investment in equipment, servers, networks, and application development. Many halal authorities and small producers lack the financial capacity to acquire new technologies. This situation necessitates alternative funding mechanisms such as government grants, international donor support, or joint industrial financing schemes. Without adequate financial support, digital halal systems may only benefit large-scale industry actors.

Improving digital literacy is a key strategy to ensure all actors can perform their roles within the blockchain-based halal system. Auditors require technical knowledge to interpret digital data, identify anomalies, and conduct system-based verification. Producers, meanwhile, need training to input information consistently and accurately. Structured training programs reduce operational errors and encourage active participation from all stakeholders.

The development of reliable technological infrastructure forms the foundation for successful blockchain implementation. Stable internet access, compatible IoT devices, and high-capacity servers must be gradually established to ensure optimal system performance. Strong infrastructure ensures that tracking processes remain uninterrupted and data can be updated in real time. Without robust technical support, the benefits of blockchain cannot be fully realized.

Public-private partnerships are a strategic mechanism to accelerate blockchain implementation in halal certification. The public sector can provide regulations and incentives, while the private sector contributes technological innovation and operational efficiency. This collaboration model enables faster knowledge transfer and more balanced cost distribution. The combination of these resources helps create a sustainable digital ecosystem responsive to technological developments.

A phased roadmap is necessary to ensure that blockchain implementation proceeds systematically and can be evaluated at each stage. The process can begin with pilot projects in the most prepared sectors—such as meat or processed food—before expanding to others. Subsequent stages include regulatory adjustments, infrastructure strengthening, and digital application refinement. This staged approach minimizes the risk of failure while allowing room for technological improvement.

Continuous evaluation is an essential component of blockchain implementation, as technological developments and industry dynamics evolve over time. Evaluation mechanisms allow policymakers to identify system weaknesses, measure effectiveness, and update security protocols. Furthermore, evaluation ensures that the system continues to comply with halal standards and remains relevant. This oversight process strengthens long-term system reliability.

The adoption of blockchain in Nigeria's halal certification system offers significant opportunities to transform oversight mechanisms that have long faced numerous limitations. This technology can enhance credibility, efficiency, and transparency through record-keeping that is resistant to manipulation. However, its success depends on regulatory readiness, infrastructure availability, and stakeholder competence. If these elements are adequately addressed, Nigeria can build a modern halal system capable of competing on a global scale.

CONCLUSION

This study demonstrates that blockchain offers a comprehensive solution for modernizing Nigeria's halal certification system through mutually reinforcing structural, technical, and governance approaches. Structurally, the technology provides a distributed recording framework that strengthens the integrity of the certification process. From a technical perspective, blockchain's ability to maintain traceability and data consistency directly addresses long-standing challenges related to transparency and accountability within halal authorities. In terms of governance, the digital system creates opportunities to improve audit mechanisms and enhance multi-stakeholder coordination in a more systematic and efficient manner.

Based on these findings, further research is needed to examine the readiness of Nigeria's digital ecosystem more thoroughly, including aspects of security, industry adaptation, and the effectiveness of blockchain-based pilot models in priority food sectors. Stakeholders are encouraged to formulate a phased implementation strategy that includes regulatory strengthening, capacity building for halal authorities, and strategic partnerships between government, industry, and research institutions. Such a gradual approach enables innovation to progress with minimal risk while ensuring that the digital transformation of halal certification is sustainable and delivers tangible benefits for society and the national economy.

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