Artificial Intelligence for Halal Integrity: A Qualitative Thematic Literature Analysis of Shariah Compliance and Ethical Accountability

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Abstract

The development of artificial intelligence opens up new opportunities to strengthen halal integrity in the halal ecosystem, especially through improving the ability to verify, trace, identify risks, and detect fraud. While offering various benefits, the use of AI also raises a number of important issues related to compliance with sharia principles, human supervision, and ethical responsibility. This research aims to examine the role of AI in supporting halal integrity and identify the sharia principles and ethical guidelines needed to ensure its responsible application. This research uses a qualitative literature review approach with thematic analysis. Relevant academic literature was identified through Google Scholar with a primary focus on publication in 2021–2025. The selected literature was then analyzed and grouped into three main themes, namely the application of AI in maintaining halal integrity, compliance with sharia principles and human supervision, and ethical accountability. The results of the study show that AI can play a supporting role in strengthening the halal verification process, improving traceability, analyzing information, and identifying potential risks in the halal ecosystem. However, the output of artificial intelligence cannot be an independent determinant of Sharia legitimacy because decisions that require interpretation, contextual assessment, and religious authority still require competent human supervision. Responsible integration also requires transparency, clarity, accountability, and data integrity. This research proposes an artificial intelligence-based halal integrity framework that places technology as a supporting layer, while Sharia governance and human ethical responsibility remain the foundation for creating a trustworthy halal ecosystem.

Keywords: artificial intelligence, halal integrity, sharia compliance, halal ecosystem, ethics

Introduction

The development of artificial intelligence (AI) has opened up new avenues for transformation in various sectors, including the halal industry. In the halal ecosystem, artificial intelligence can assist in verification, traceability, risk identification, fraud detection, raw material analysis, and supply chain management. These developments show that AI is evolving from just an automation tool to a tool to improve efficiency and analytical capabilities to ensure the integrity of halal products and processes. The development of AI research in the halal industry reflects the growing interest of academia in the use of AI as well as in the fields of certification, supply chain, and the development of digital halal ecosystems (Azwar & Usman, 2025). Thus, the integration of artificial intelligence (AI) is worth researching as the complexity of the need for halal systems that provide traceable and verifiable information is increasing.

However, the challenges in applying AI to the halal ecosystem are not only limited to the efficiency of the technology itself. Halal integrity lies not only in the system's ability to recognize patterns, process data, and identify risks, but also in compliance with sharia principles and regulations. Studies on halal supply chains show that the complexity of supply chains can pose a number of integrity issues, and that Industry 4.0 technologies such as AI have the potential to help address these issues (Ellahi et al., 2025). On the other hand, the application of AI in halal certification and auditing must be in accordance with the regulatory framework and sharia principles. Therefore, the use of technology cannot be separated from relevant oversight mechanisms (Aisyah et al., 2025). Thus, the main issue is the boundary that separates AI's ability to provide analysis and information from the authority of human judgment on matters that have sharia consequences.

A number of previous studies have developed various approaches to answer this problem. Studies on the application of AI in the halal supply chain show that this technology can help supply chain management while improving the ability to identify and monitor processes to maintain product halalness (Ghalih et al., 2025). Meanwhile, another study proposes the use of AI combined with blockchain to support religious compliance, certification processes, and traceability in the halal food supply chain (Khan et al., 2025). In terms of governance, the Maqasid al-Shariah-based approach has also been used to review the concept of halal governance to suit the development of the digital economy (Wahab & Mahdiya, 2026). These findings show that AI is more appropriately used as a supporting technology in the management of halal processes. Meanwhile, the fulfillment of sharia principles and the implementation of halal governance still requires adequate institutional support and human supervision. This view is in line with the research framework that places AI as a means to strengthen halal integrity, not to replace expertise in the field of sharia or human judgment in decision-making.

Although various studies have discussed the use of AI in the halal industry, existing studies still tend to separate aspects of technological capabilities, sharia compliance, and human ethical responsibility. Research that focuses on the application of AI in the halal industry generally highlights the development of applications and the opportunities offered by the technology. However, how the use of AI needs to be directed and limited through Shariah oversight, human judgment, transparency, and accountability have not always been discussed in an integrated conceptual framework. This issue needs attention because the use of AI in decision-making can pose challenges, such as difficulty in explaining the process and results of decisions (explainability), lack of transparency, potential bias, data integrity issues, and unclear responsibility when the results provided by the system do not match the actual conditions. In a

broader context, the literature on AI ethics also emphasizes the importance of transparency and accountability to build trustworthy AI systems(Lund et al., 2025). Therefore, an approach is needed that is able to integrate the capabilities of AI technology with sharia authorities and human ethical responsibility to maintain halal integrity as a whole.

Based on the research gap, this study aims to analyze the role of artificial intelligence (AI) in supporting halal integrity while still paying attention to sharia compliance, human supervision, and ethical accountability. Through a qualitative literature review approach, this study synthesizes academic literature to develop a trustworthy AI-enabled halal integrity conceptual framework, without testing the technical performance of a particular AI system. This framework includes three main components, namely AI as an analytical tool for verification, traceability, and risk identification; sharia governance as a normative foundation; and human supervision and ethical accountability as a control mechanism. The contribution of the research lies in affirming the relationship and functional limits of the three components. The results of the AI analysis function as a decision support and risk indicator, not as an independent determinant of halal status. Decisions that require sharia assessment remain the authority of competent humans and institutions, while transparency, explainability, accountability, and data integrity ensure a traceable and accountable process. This framework complements AI–blockchain studies that focus on technology and traceability, halal governance that emphasizes sharia governance, and trustworthy AI that discusses AI ethics in general. Thus, this research formulates sharia and ethical principles to ensure that the use of AI in the halal ecosystem remains within the limits of human authority and responsible governance.

Literature Review

Artificial Intelligence and Halal Integrity

Halal integrity is related to efforts to maintain the halalness of products at every stage of their life cycle, starting from the procurement of raw materials, production and processing processes, storage, transportation, to distribution. Thus, halal integrity is not enough to be judged only by the halal status of the final product, but also needs to be supported by the reliability of information about the materials used, production processes, suppliers, and product movements along the supply chain (Mohamed et al., 2020). In the development of the halal ecosystem, artificial intelligence (AI) is starting to receive attention because of its ability to help the process of identification, analysis, monitoring, and data-driven decision-making. A concurrent review study conducted by Nawaz et al. (2025) shows that technologies such as machine learning, computer vision, and natural language processing can be used to support product authentication, quality control, supply chain transparency, certification, and halal compliance monitoring (Nawaz et al., 2025). In the development of the halal ecosystem, artificial intelligence (AI) is starting to receive attention because of its ability to help the process of identification, analysis, monitoring, and data-driven decision-making. A concurrent review study conducted by Nawaz et al. (2025) shows that technologies such as machine learning, computer vision, and natural language processing can be used to support product authentication, quality control, supply chain transparency, certification, and halal compliance monitoring.

AI for Verification, Authentication, and Ingredient Screening

One of the relevant applications of AI in maintaining halal integrity is verification and authentication, including ingredient screening (Raihan, 2024). In this case, AI can help identify,

classify, and analyze information related to ingredients, product composition, suppliers, and supporting documents for halal compliance. Nawaz et al. (2025) explained that AI technology, especially machine learning and computer vision, has the potential to support product authentication and halal compliance monitoring. Meanwhile, Sunmola et al. (2025) developed an AI–blockchain framework that combines machine learning and knowledge graphs to detect potential inconsistencies in the source and composition of ingredients. In this approach, AI helps check compliance and flag information that needs to be further traced, while blockchain provides verifiable records of material provenance.

The findings suggest that AI is particularly useful for initial screening and analytical verification, as it is able to speed up information processing and help find patterns or non-conformities that may be difficult to identify through manual checks. However, the use of AI has limitations that need to be considered. The results of the resulting classification or marking are highly dependent on the data, models, and criteria used so that they cannot be immediately considered as definitive evidence of the halal status of a product. For example, Sunmola et al. (2025) place AI as part of the pre-certification process and compliance checks, rather than as a substitute for the entire halal certification stage. Therefore, AI-based material screening is more appropriately used as an initial inspection and decision-making tool, while final determination still requires verification of relevant halal compliance information and procedures.

AI for Supply Chain Traceability and Transparency

Another important AI function in maintaining halal integrity is traceability (Azwar & Usman, 2025), namely the ability to track the origin, movement, and history of product information along the supply chain. This aspect needs attention because halal integrity can be threatened when information about the origin of ingredients, production processes, storage, transportation, and distribution is not adequately available. Ellahi et al. (2025) identified a number of problems in the halal meat supply chain, including limited traceability and transparency, unreliable documentation, cross-contamination, and fraud. The study shows that Industry 4.0 technology, including AI, has the potential to improve the efficiency, transparency, and monitoring capabilities of the supply chain.

In its application, AI and blockchain have complementary roles (Mohanty, 2024). AI focuses on information processing and analysis (Fakhlina et al., 2025), while blockchain helps provide verifiable records of transactions and product provenance (Betz, 2021). Sunmola et al. (2025) combine the two technologies in a halal compliance framework. In this framework, AI is used to check compliance, detect non-conformities, and help manage risks, while blockchain supports product origin tracing. The framework covers various aspects, from raw materials and production processes to logistics, and describes the use of knowledge graphs, machine learning, and smart contracts in the halal pre-certification process (Sunmola et al., 2025).

However, the application of traceability technology does not necessarily guarantee the maintenance of halal integrity. The system's ability to trace information still depends on the accuracy, completeness, and reliability of the origin of the data entered. This means that traceability makes it easier to trace information, but does not automatically ensure that the information is correct and accountable. This needs to be considered because it is not enough to only support the digital track record, but also requires verification to ensure the validity of the information and its conformity with halal requirements.

AI for Risk Detection and Fraud Detection

The third function of AI in supporting halal integrity is to detect risks and potential fraud (Afdhalia, 2025). AI's ability to process large amounts of data and recognize unusual patterns can help identify risk indications (Syaifuddin, 2025). In the halal supply chain, this ability can be used to find mismatches in information related to raw materials, suppliers, certification documents, and product distribution activities. Ellahi et al. (2025) also identified fraud, counterfeiting, cross-contamination, non-compliance, and unreliable documentation as a number of problems that threaten the integrity of the halal meat supply chain. Therefore, AI has the potential to be a tool to monitor supply chain activities and detect risks early, especially in systems that involve many parties and complex processes.

Sunmola et al. (2025) show the application of this function through an AI–blockchain framework that leverages AI to detect potential non-conformities in the procurement and composition of materials, while supporting risk management. However, anomalies detected by AI do not necessarily prove fraud or violations of halal regulations. The results of AI analysis are more appropriately understood as an initial signal of a risk that needs to be followed up through further examination, rather than as a basis for making a final decision. This is important because unusual patterns in the data can be caused by various factors and do not necessarily indicate a violation of halal requirements.

Synthesis of AI Functions and Implementation Limitations

Overall, various studies show a similar pattern, namely that AI is most useful when used to strengthen analytical capabilities in halal assurance systems. However, the reliability of the results still depends on the quality of the data, the context of implementation, and the inspection process carried out. In verification and screening of materials, AI helps to group information as well as detect possible non-conformities. In the traceability aspect, AI helps analyze information related to supply chain activities. Meanwhile, in risk and fraud detection, AI helps recognize patterns or anomalies that need to be investigated further. These three functions complement each other in supporting halal integrity, but cannot be used independently to establish the halal status of a product.

Based on this synthesis, the role of AI in strengthening halal integrity can be understood through a series of interrelated functions, ranging from AI analysis capabilities to support ingredient verification and screening, to strengthening traceability, to helping detect risks. This series is expected to contribute to strengthening halal integrity, but it does not mean that the application of AI automatically guarantees product halal. Its effectiveness is still influenced by the quality and completeness of data, supply chain conditions, system design, and validation processes applied. Sunmola et al. (2025) show the potential for AI and blockchain integration in supporting halal compliance, although the study is still in the form of a conceptual framework equipped with implementation illustrations at the pre-certification stage. In line with that, Ellahi et al. (2025) emphasized that the application of Industry 4.0 technology in the halal meat supply chain is still limited in terms of practical implementation evidence, so further empirical research is needed to test its application in real conditions.

Therefore, the growth of publications on AI and the halal industry needs to be distinguished from the maturity of the evidence for its implementation. The increasing number and variety of research shows the growing academic interest in AI in authentication, certification, traceability, and halal supply chains, but it cannot be directly interpreted that the

technology has been widely applied and proven effective in diverse operational conditions. The study of Ellahi et al. (2025) specifically shows that the use of Industry 4.0 technology in the halal meat supply chain is still a developing area and relatively under-explored empirically. Thus, the current literature is stronger in demonstrating the functional potential of AI than providing adequate evidence regarding the effectiveness of AI implementation broadly in ensuring halal integrity.

Overall, the previous literature supports the understanding that AI is a technological enabler for halal integrity through verification, ingredient screening, traceability, and risk/fraud detection. However, these capabilities primarily generate analytical information and risk signals that still require interpretation and validation. These findings serve as the basis for further discussion of why AI cannot stand alone in Sharia decisions and why the integration of Shariah governance, human oversight, and ethical accountability is necessary to build trustworthy AI-enabled halal integrity.

Sharia Compliance and Human Supervision

Halal integrity and Shariah compliance are interrelated, but not identical, concepts. Halal integrity refers to the conditions and processes that ensure the halal status of a product, process, and information is maintained throughout the value chain, starting from material procurement, production, storage, transportation, to distribution and consumption (Soon et al., 2016). In the perspective of halal supply chain, halal integrity is comprehensive because halal status is not only determined at the point of production or on the final product, but must be maintained throughout the movement of products from source to consumer. Mohamed et al. (2020) place halal integrity assurance in relation to supply chain management, while halal supply chain literature explains that integrity assurance includes procurement, production, packaging, labeling, logistics, retail, and consumption (Mohamed et al., 2020). Thus, halal integrity can be understood as a condition/process of assurance that ensures that halal attributes and status are not damaged, changed, or compromised along the value chain.

Meanwhile, Shariah compliance is a normative and authoritative dimension that is the basis for determining whether the product, process, or activity complies with Sharia regulations. The literature on halal supply chain compliance shows that the production process and supply chain of halal products must meet the principles of Islamic law from farm to fork, so that halal integrity cannot be separated from compliance with Sharia requirements (Soon et al., 2016). In this context, Shariah compliance does not simply indicate that a process has followed certain operational procedures, but shows its conformity with the normative provisions that are the basis for halal determination. Thus, the relationship between the two concepts is normative–operational: Shariah compliance provides standards and basis for assessment, while halal integrity indicates the extent to which halal status and assurance are maintained consistently in practice along the value chain. The literature on halal biotechnology products, for example, explicitly links Shariah compliance with the application of halal principles in the production process and places halal supply chain management as a mechanism for maintaining halal integrity (Rahman & Razimi, 2023).

This distinction is important in the use of AI. AI can help examine material data, identify potential non-conformities, trace supply chain information, and provide risk signals related to halal integrity. However, these capabilities do not automatically provide the authority to establish that a product or process has complied with Shariah compliance. Determination of

Sharia compliance may require interpretation of relevant provisions, case contexts, and institutional authorities. Therefore, AI can support assurance mechanisms to maintain halal integrity, but the normative basis and authority for assessing Shariah compliance remain within Sharia governance mechanisms and competent human oversight. This position is consistent with the halal AI–blockchain framework that puts technologies in place to support compliance checking, irregularity identification, and traceability, while compliance processes still require institutional vetting mechanisms.

Abu Bakar et al. (2025) examined Sharia and regulatory perspectives in AI-based halal audits through a qualitative meta-analysis of ten articles published between 2022 and 2025. Their findings suggest that discussions on the adoption of AI in halal audits primarily emphasize instrumental considerations, including operational efficiency, digital transformation, and cost reduction. Regulatory compliance receives attention, while normative considerations related to religious and ethical obligations are relatively underemphasized. Therefore, the study highlights the importance of integrating technology adoption with Sharia principles and regulatory requirements rather than treating operational efficiency as the primary goal of halal audits (Aisyah et al., 2025).

These differences reveal important limitations of technology-based approaches to halal governance. AI systems can classify ingredients, identify inconsistencies, or recommend further checks based on available information. Nevertheless, such results remain dependent on the criteria, data, and rules that are incorporated into the system. Technically consistent classification cannot automatically be equated with a legitimate Sharia determination. The distinction between analytical capabilities and religious authorities is particularly relevant when information is incomplete, conflicting, or requires interpretation beyond predetermined classification criteria.

The framework proposed by Sunmola et al. (2025) provides a useful foundation for understanding the relationship between automated analytics and institutional decision-making. Their approach integrates AI-based classification with blockchain-powered representations of knowledge and compliance procedures. Importantly, this framework includes mechanisms by which anomalies can trigger further scrutiny, illustrating the role of technology systems in supporting compliance workflows rather than eliminating the need for institutional verification (Sunmola et al., 2025) .

Human surveillance is therefore essential for the integration of responsible AI in the halal ecosystem (Ali et al., 2024). In this context, supervision involves the participation of competent personnel and relevant authorities in reviewing AI-generated information, interpreting compliance requirements, resolving uncertain cases, and maintaining responsibility for consequential decisions. This kind of supervision is not only a technical safeguard but also an institutional requirement to ensure that technological processes remain aligned with the normative foundations of halal assurance.

The relationship between AI and Sharia governance can be conceptualized as complementary, not substitutive. AI provides analytical capacity, while qualified human judgment and legitimate institutional authority provide the interpretation and governance functions necessary for Sharia compliance. This relationship sets a fundamental boundary for responsible technology adoption: automation can support halal assessment, but automation alone does not provide Sharia legitimacy.

AI Ethics and Accountability

Ethics in the application of artificial intelligence (AI) are not only related to the technical performance of the system, but also to the consequences of using AI output on decision-making and those responsible for the decision. The NIST AI Risk Management Framework (AI RMF) places *validity and reliability, accountability and transparency,* and *explainability and interpretability* as important characteristics of *trustworthy AI* and affirms that these characteristics are socio-technical because they are influenced by data, model design, organizational decisions, and human interaction with AI systems (Tabassi, 2023). UNESCO (2021) also places *human oversight and determination, transparency and explainability,* and *responsibility and accountability* as ethical principles that are needed throughout the life cycle of AI. Thus, ethical issues arise when the technical limitations of the system have the potential to translate into decisions that have consequences for humans, organizations, or other affected parties (UNESCO, 2021) (Tabassi, 2023). In the context of halal integrity, the relationship between technical characteristics and the consequences of such decisions becomes important because AI outputs can be used as part of the process of inspection, risk assessment, and halal compliance assurance.

One of the technical characteristics that acquires an ethical dimension in this context is reliability. *Reliability* becomes an ethical issue when AI output is used as a basis or input for decisions that have consequences for other parties. NIST explains that a trustworthy AI system needs to have a level of validity and reliability that is appropriate to the context of its use because failure of the system to work as intended can increase the risk of negative consequences (Tabassi, 2023) (Tabassi, 2023). Nastoska et al. (2025) also place reliability as one of the important dimensions in the assessment of the trustworthiness of AI systems. In the context of halal, these consequences become relevant because AI can be used to conduct halal compliance checks, identify irregularities in the source and composition of ingredients, and support risk management (Sunmola et al., 2025). Therefore, when the output is used in the halal assurance process, misclassification or identification is not only a technical performance issue, but can affect the information used to assess ingredients, processes, or halal compliance (Sunmola et al., 2025). Thus, the demand for reliability acquires an ethical dimension because there are consequences for decisions when unreliable AI outputs are used in the halal assurance process (Tabassi, 2023) (Sunmola et al., 2025).

However, the reliability of the output alone is not enough to ensure that the use of AI takes place responsibly. Parties using AI results also need to be able to understand and evaluate how an output is generated, especially when the output is considered in decisions that have consequences. In this case, interpretability and explainability have an ethical dimension because humans using AI outputs need to have an adequate basis to understand and evaluate the results that influence decisions. NIST distinguishes explainability as a representation of the mechanisms underlying the operation of AI systems and interpretability as the meaning of system outputs in the context of their functional objectives; both support an understanding of the system's functions, outputs, and potential impacts (Tabassi, 2023). The AI trustworthy literature also places interpretability as an important element for assessing whether the system's output can be adequately understood by humans (Nastoska et al., 2025). In the halal context, this need is relevant when AI identifies irregularities in sourcing or ingredient composition and provides information for compliance checks (Sunmola et al., 2025). The Sunmola et al. (2025) framework, for example, uses knowledge graphs alongside machine learning to support

information representation and halal pre-certification processes. Therefore, interpretability not only serves as a technical characteristic of the model, but also allows auditors or authorities to assess the basis of information before AI outputs are used in decisions related to halal compliance (Tabassi, 2023) (Sunmola et al., 2025).

The need to understand and evaluate the output of AI further leads to the problem of human oversight. Human oversight is an ethical issue because the increased complexity and autonomy of AI systems can reduce the ability of humans to understand, evaluate, and intervene in system outputs. Holzinger et al. (2025) show that the complexity, opaque nature, and increasing autonomy of AI systems raise questions about whether meaningful human oversight can still be effectively maintained (Holzinger et al., 2025). UNESCO (2021) places human oversight and determination as an ethical principle of AI and affirms that final responsibility and accountability cannot be transferred to AI systems. In the context of halal, human oversight is becoming increasingly important because AI can support the process of checking compliance and identifying irregularities, but the use of such technology remains within the framework of halal certification and compliance (Sunmola et al., 2025). The study by Aisyah et al. (2025) also shows the need to link the application of AI in halal audits with Sharia frameworks and regulations, not just with efficiency and technological transformation (Aisyah et al., 2025). Thus, human oversight functions as an ethical and institutional mechanism that ensures that the use of AI as a decision-support technology does not transfer the authority of valuation that requires Sharia interpretation to algorithmic systems (Aisyah et al., 2025) (Holzinger et al., 2025) (UNESCO, 2021).

In order for human supervision to take place meaningfully, the process of using AI also needs to take place transparently. Transparency has an ethical dimension because parties who use or are affected by AI systems need to have adequate information about how the system is used, the purpose of its use, and the position of AI outputs in the decision-making process (UNESCO, 2021) (Tabassi, 2023). NIST links transparency to the availability of information about AI systems and decision-making processes, while UNESCO (2021) links transparency and explainability to rights protection, oversight, and accountability. In the context of halal assurance, transparency becomes relevant because AI can be used for compliance checking, irregularity identification, and risk management, while blockchain can provide information on product provenance (Sunmola et al., 2025). Therefore, stakeholders need to be able to distinguish whether an outcome is an automatic classification, an AI recommendation, supporting information, or a decision that has been validated by the authoritative party. This distinction is important so that the use of technology does not obscure the process that produces halal decisions and the parties responsible for those decisions (UNESCO, 2021) (Sunmola et al., 2025).

Clarity about the process and role of AI is ultimately directly related to the issue of accountability. *Accountability* is an ethical issue because the use of automated systems does not eliminate the need to identify those responsible for decisions and their consequences. NIST links *accountability* to transparency and organizational structure that allows accountability for AI systems to be established and managed (Tabassi, 2023). UNESCO (2021) explicitly places responsibility and accountability as ethical principles of AI and emphasizes that AI actors should be held accountable according to their role in the system lifecycle. In the context of halal auditing and compliance, the issue becomes relevant when AI outputs contribute to the assessment of materials, suppliers, processes, or compliance, as the use of AI does not remove

the responsibility of the institutions and humans who develop, operate, validate, and use the system (Aisyah et al., 2025) (Sunmola et al., 2025). Therefore, accountability is needed to prevent unclear allocation of responsibility when the AI output used in the halal assurance process turns out to be wrong or disputed (UNESCO, 2021) (Tabassi, 2023).

In addition to clarity about who is responsible, accountability also depends on the quality of the information on which the AI system works. *Data integrity* has an ethical dimension because the reliability of AI outputs depends on the quality, completeness, consistency, and provenance of the information processed by the system. NIST places data as one of the critical components in risk management throughout the AI lifecycle and emphasizes the need for a process of measuring and managing risks related to data and the context in which it is used (Tabassi, 2023). UNESCO (2021) also places *data governance* as an important part of ethical AI governance, including attention to data quality, security, privacy, and data management mechanisms throughout the AI lifecycle. In the context of halal, Sunmola et al. (2025) show that AI–blockchain-based halal compliance systems rely on information regarding ingredients, composition, production processes, logistics, and product provenance. Therefore, inaccurate ingredient data, incomplete supplier information, or unverifiable provenance can affect the quality of the outputs used in the halal compliance process (Sunmola et al., 2025). Data integrity is thus not only a technical prerequisite for AI performance, but also part of the ethical responsibility to ensure that decisions or recommendations that have consequences for halal assurance are not built on untrustworthy information (UNESCO, 2021) (Tabassi, 2023) (Sunmola et al., 2025).

Thus, the six aspects do not stand as separate principles, but rather form a series of interrelated governance requirements. Reliability is related to the risk of using incorrect outputs; interpretability and transparency allow humans to understand and examine the basis of outputs; human oversight maintains human capacity to evaluate and intervene; accountability ensures that responsibility remains allocated, to actors and institutions; while data integrity ensures that analysis is built on trustworthy information (UNESCO, 2021)(Tabassi, 2023)(Holzinger et al., 2025)(Nastoska et al., 2025). In the context of halal, these principles take on special significance because AI can contribute to compliance checking, irregularity detection, risk management, and pre-certification, while decisions that have Sharia consequences remain within the governance and halal compliance environment (Sunmola et al., 2025) (Aisyah et al., 2025). Thus, trustworthy AI-enabled halal integrity demands not only a system that is technically capable of generating outputs, but also a process that allows those outputs to be examined, explained, supervised, and accounted for before being used in decisions related to halal integrity and compliance (UNESCO, 2021)(Tabassi, 2023)(Sunmola et al., 2025).

Methods

This study uses a qualitative library research approach with the thematic literature analysis method. The literature was searched through Google Scholar using a combination of keywords and Boolean operators, namely "artificial intelligence" AND halal, "artificial intelligence" AND "halal integrity", "artificial intelligence" AND "halal compliance", "artificial intelligence" AND halal AND Shariah, AI AND halal AND "human oversight", and AI AND halal AND ethics/accountability. Each combination was conducted as a separate search to reach a variety of relevant terms. The search was conducted with a focus on publications in 2021–2025, while older literature was used selectively when relevant as a conceptual foundation. The

combination of keywords, search dates, and number of results was recorded to support the transparency of the search process, taking into account Google Scholar's limitations in search reproducibility (Haddaway et al., 2015) (Gusenbauer, 2020).

Literature selection is conducted based on inclusion and exclusion criteria. Literature is included when discussing the application of artificial intelligence in authentication, verification, traceability, halal supply chains, or halal compliance, as well as relevant to Sharia compliance, governance, human supervision, or ethical accountability. Literature is excluded if it is not relevant to the focus of the research, duplicates, or does not provide adequate information for analysis. The selection process includes recording search results, removing duplicates, checking titles and abstracts, and reviewing the content of publications that meet the initial criteria. The number of publications at each stage is recorded, including initial results, results after duplication removal, publications that pass screening, and final numbers analyzed. The recording of these search and selection stages supports the transparency of literature review reporting (Haddaway et al., 2015).

The analysis was carried out using thematic analysis which refers to Braun and Clarke (2006), including in-depth literature reading, initial coding, theme development, theme review, theme definition and naming, and thematic synthesis (Braun & Clarke, 2006). The literature is grouped into three main themes, namely (1) the application of AI to support halal integrity, (2) Sharia compliance and human supervision, and (3) ethical accountability in the application of AI in the halal ecosystem. Interthematic synthesis is used to identify conceptual patterns and gaps and develop a trustworthy AI-enabled halal integrity conceptual framework. The use of the coding, development, and theme review stages follows the thematic analysis framework of Braun and Clarke (2006).

Results and Discussion

AI as an Enabler of Halal Integrity

The results of the thematic analysis show that AI can be positioned as a technological enabler in strengthening halal integrity, especially through four functions that appear consistently in the literature, namely verification/authentication, traceability, risk identification, and non-conformity detection. This synthesis is constructed by comparing the technological focus, findings, application context, and limitations of the analyzed studies, as summarized in Table 1. Mohamed et al. show that halal integrity assurance is related to the management of processes and supply chain network structures, so halal integrity needs to be maintained on an ongoing basis, not just checked on the final product. In the development of AI research, Nawaz et al. identified the use of machine learning, computer vision, and other analytical technologies to support authentication, quality control, supply chain transparency, certification, and halal compliance monitoring. Furthermore, Ellahi et al. identified cross-contamination, fraud, falsification, and limited traceability as issues relevant to the integrity of halal supply chains and demonstrated the potential of Industry 4.0 technologies, including AI, to improve information monitoring and management. Sunmola et al. further demonstrated that AI can be used for compliance checks, irregularity identification, and risk management, while blockchain can support the recording and tracing of provenance within the framework of halal compliance. Meanwhile, Azwar and Usman's bibliometric mapping shows that the development of AI research in the halal industry has a lot to do with supply chain management, blockchain, traceability, and consumer trust. Thus, the synthesis of cross-studies shows a relatively

consistent pattern: AI mainly provides value through improving information processing capabilities, verification, tracing, and identifying patterns or anomalies relevant to halal integrity. However, the literature also shows that technological capabilities and research growth do not by themselves prove the success of AI implementation in all halal industry contexts. Therefore, in this study, AI is positioned as an analytical layer that supports halal assurance, not as a mechanism that independently determines the halal status of a product.

Table 1. Literature Synthesis on the Role of AI as an Enabler of Halal Integrity

Studies/Resources	AI/Technology Focus	Findings	Limitations/Context	Implications for Halal Integrity
Mohamed et al. (2020)	Halal supply chain management and *halal integrity assurance*	The management of the process and the structure of the supply chain network is related to *halal integrity assurance*.	Focus on the food and beverage industry in Malaysia.	Halal integrity needs to be maintained throughout the supply chain; technology needs to be placed in *a broader* assurance process.
Nawaz et al. (2025)	*Machine learning*, *computer vision*, NLP, AI, and related technologies	AI has the potential to support authentication, *quality control*, supply chain transparency, certification, and halal monitoring.	Review-based; shows the development and potential of the application, not evidence that the entire application has been widely implemented.	AI supports verification and authentication functions as part of the *halal assurance process*.
Ellahi et al. (2025)	Industry 4.0 Technologies, including AI	Identify cross-contamination, fraud, falsification, and limited *traceability* as halal supply chain integrity issues.	Focusing on the halal meat supply chain; the level of evidence of inter-technology implementation.	AI has the potential to support monitoring, transparency, risk identification, and non-conformity detection.
Sunmola et al. (2025)	AI–blockchain, *knowledge graph*, *machine learning*, *smart contracts*	AI is used for compliance checks, irregularity identification, and risk management; blockchain supports *provenance*.	Implementation frameworks and examples are *pre-certification-oriented*; they cannot yet be treated as proof of universal implementation.	AI serves as an analytical layer that can strengthen verification and risk management, while blockchain strengthens *traceability*.
Azwar & Usman (2025)	AI research mapping in the halal industry	Themes that develop include *supply chain management*, blockchain, *traceability*, and *consumer trust*.	Bibliometric analysis describes the development of the literature, not the effectiveness of technology implementation.	Reinforcing that verification, *traceability*, and supply chain management are important areas in the development of halal AI.

Source: Processed by the author based on a synthesis of literature.

Based on Table 1, the synthesis is not directed to state that all AI functions have been proven to be empirically effective, but rather to identify patterns of technological functions that are consistent in the literature. The pattern shows that AI's contribution to halal integrity is primarily in the ability to process information, perform verification or classification, trace supply chain information, and detect patterns and irregularities that can be the basis for further examination. Nawaz et al. specifically place AI as a technology that can support authentication and traceability, while Sunmola et al. extend these functions through the integration of AI with

blockchain for compliance, risk management, and provenance checks. At the same time, Ellahi et al.'s findings suggest that integrity issues such as fraud, falsification, and cross-contamination are supply chain issues that require monitoring and control mechanisms, so AI functions are more appropriately understood as supporting the risk identification and management processes than as a substitute for the overall halal assurance mechanism.

Thus, the first proposition built from the literature synthesis is that AI plays an enabler for halal integrity through strengthening the functions of verification, traceability, and risk/fraud detection, but these contributions are supportive and depend on the quality of information, the context of implementation, as well as validation and halal governance mechanisms. This proposition is the basis for discussion in the next subsection regarding the limits of AI's role in Shariah compliance and the need for human supervision.

Why AI Can't Stand Alone in Sharia Decisions

AI can process data, recognize patterns, classify information, and provide recommendations based on available rules or data. However, this ability does not automatically give Sharia legitimacy to the resulting decisions. In the context of halal, certain decisions may require interpretation of Sharia provisions, an understanding of the context of the case, and institutional authority that cannot be reduced to mere algorithmic classifications (Aisyah et al., 2025).

These findings are important because AI systems work based on data, models, parameters, and rules used in the development process. In the context of halal, these conditions indicate a boundary between technical classification and Shariah judgment. Technical classification refers to AI's ability to process data, match information to available criteria, identify patterns or anomalies, and generate classifications and risk signals. In contrast, Shariah judgment is a normative assessment of the suitability of a material, process, or condition with Sharia provisions that may require interpretation of relevant context and provisions. Therefore, AI output needs to be positioned as an analytical result that must be validated by humans, not as a final Sharia decision. Sunmola et al. (2025) show that AI can be used to automate halal compliance checks, identify potential irregularities in material sources and compositions, and support risk management, but these functions are placed within a broader compliance and certification framework. Thus, the limit of AI's authority is on the function of processing and classifying information, while validation of results and assessments that require Sharia interpretation still requires human oversight by parties with relevant competencies and authority. This is in line with Holzinger et al. (2025) who emphasize the importance of meaningful human oversight when AI systems are used in complex contexts or have important consequences. If AI results show ambiguous, incomplete, conflicting, or indicate a risk of non-conformity, the results need to be escalated for further human examination and, if normative interpretation is required, forwarded to the competent party or authority. This distinction is also in line with Abu Bakar et al. (2025), who emphasized that the application of AI in halal audits needs to integrate Sharia and regulatory perspectives, not just efficiency and technical capability considerations.

In this framework, human oversight is not just a technical safeguarding mechanism, but part of halal governance. Humans with relevant competencies are still needed to review AI-generated information, interpret relevant provisions, resolve ambiguous cases, and make decisions that have consequences for compliance. This principle is in line with UNESCO's

Recommendation on the Ethics of Artificial Intelligence which emphasizes that AI systems should not replace human responsibility and accountability. UNESCO also places human oversight, transparency, accountability, and fairness as important principles in AI governance (UNESCO, 2021).

These findings resulted in the principle of automation ≠ Shariah legitimacy. This means that the higher the automation capabilities of a system, the more important it is to be clear about who has the authority to make the final decision. AI can be positioned as *a decision-support technology*, while the legitimacy of halal decisions remains within a governance structure involving relevant authorities and experts. This position is also in line with the framework of Sunmola et al. (2025), which positions AI and blockchain-based processes as supporting compliance flows, rather than as removing the need for institutional verification (Sunmola et al., 2025).

Thus, the relationship between AI and Sharia governance is more appropriately understood as a complementary relationship, not a substitution. AI provides computational capabilities to process and analyze information at scale, while humans and institutional authorities provide interpretation, contextual assessment, and decision accountability functions. Models like this allow technology to be leveraged to improve efficiency without transferring normative authority to algorithms (UNESCO, 2021).

Ethical Accountability in AI-Based Halal Systems

The application of AI in halal assurance systems is not sufficiently assessed based on its technical capabilities. The system must also meet ethical requirements related to transparency, explainability, accountability, and data integrity. This is important because AI outputs can be used as part of certification processes, supplier evaluation, risk identification, and compliance monitoring. The NIST AI Risk Management Framework places accountability and transparency, explainability and interpretability, and harmful bias management as important characteristics of trustworthy AI (Tabassi, 2023).

Transparency in AI systems for halal assurance needs to be understood operationally as openness about the source and origin of data, the function of AI in the halal assurance process, the limits of the use of the system, and the position of AI outputs in decision-making. UNESCO places transparency and explainability as ethical principles that need to be applied in accordance with the context, purpose of use, and impact of an AI system, so that transparency does not only mean opening up as much information as possible, but providing relevant information so that the use and consequences of the system can be understood by interested parties (UNESCO, 2021).

In the context of halal, the first aspect can be realized through traceability regarding the origin of ingredient data, supplier information, certification data, and production process information used as the basis for AI analysis, because information about the origin of ingredients and production processes is an important part of the AI- and blockchain-based halal compliance framework developed by Sunmola et al. (2025). The second aspect is related to openness regarding the role of AI, namely whether the system is used to conduct ingredient screening, verification, traceability, risk detection, or provide decision support, as shown in the framework of Sunmola et al. (2025) which uses AI for compliance checks, identification of potential irregularities, and risk management. The third aspect concerns the limits of the use of AI, especially the clarity that the system's output is an analytical result or recommendation that

is used to support the inspection process, not automatically replacing the validation and decision-making process in halal certification; Sunmola et al. (2025) themselves place the AI–blockchain integration as a support for the halal certification and compliance process, not as a substitute for the entire institutional process. The fourth aspect is related to the position of AI outputs in the decision-making process, so it is necessary to distinguish whether an outcome is an automatic classification, a risk signal, a recommendation for further examination, or a decision that has been validated by humans; this principle is in line with UNESCO which affirms that AI systems should not eliminate human responsibility and accountability (UNESCO, 2021).

Meanwhile, explainability has a different focus from transparency because it relates to the ability to provide an understandable reason or justification for why AI produces certain outputs. NIST places explainable and interpretable as trustworthy characteristics of AI and emphasizes the importance of considering those characteristics throughout the design, development, use, and evaluation stages of AI systems (Tabassi, 2023). In a halal context, explainability means that when AI, for example, flags a material as risky or recommends an inspection of a supplier, there is a traceable basis for understanding the factors or information that led to the output. Sunmola et al. (2025) show that knowledge graphs can provide a more human-understandable representation of halal supply chain information, while they also note that some machine learning models are not inherently easy to interpret and therefore may require additional mechanisms to explain their outputs (Sunmola et al., 2025). Thus, transparency answers the question "what is it used, how is AI placed, and what are the limits of its use?", while explainability answers "why does AI produce certain outputs?"; both are necessary for AI output to be meaningfully examined in the halal assurance process.

The next issue is accountability. When AI output contributes to decisions that are later proven to be wrong or disputed, the use of AI should not detract from clarity about who is responsible. Responsibility should remain traceable to the human actors and institutions that design, operate, validate and use the system. UNESCO explicitly links transparency and explainability to accountability and accountability mechanisms, while NIST places accountability as one of the characteristics of trustworthy AI (NIST, 2023).

Data integrity is a very fundamental condition because the quality of AI output depends on the quality of the data processed. Inaccurate raw material data, incomplete supplier information, inconsistent certification documents, or unrecorded changes in information can result in erroneous outputs even if the AI model works by design. Sunmola et al. (2025) place data quality, information origin, privacy, and explainability as aspects that need attention in the development of AI–blockchain systems for halal compliance. Thus, the development of AI for halal requires not only good models, but also mechanisms to maintain the quality, origin, and traceability of data (Sunmola et al., 2025).

Based on this synthesis, AI errors cannot be treated solely as technical problems. Errors can become governance issues if system outputs are used in decisions that have consequences for compliance status, suppliers, certifications, or consumer trust. Therefore, halal-based AI systems require review, documentation, auditability, and escalation pathways to humans when the system produces uncertain or risky outputs. This principle is in line with the NIST framework that places risk management as a process throughout the life cycle of AI, as well as UNESCO's principles on human oversight and accountability (NIST, 2023).

Toward Trustworthy AI-Enabled Halal Integrity

AI-based halal integrity requires a combination of technological capabilities, Sharia governance, and human accountability. AI provides the ability to perform verification, traceability, risk identification, and data analysis on a larger scale; but such capabilities must be placed in governance mechanisms that ensure that decisions requiring Sharia interpretation remain under competent human oversight.

AI functions as a supportive technological layer, not as a substitute for Sharia authority. The function of AI starts from the collection and analysis of information, followed by the identification of risks or non-conformities, then the results are entered into the examination and decision-making process that remains within the governance mechanism. This model is consistent with the research of Sunmola et al. (2025), which integrates AI and blockchain to support the compliance and pre-certification process, as well as research on AI in the halal industry which shows the development of technological applications in authentication, traceability, and decision support (Sunmola et al., 2025).

The concept of trustworthy AI in this study not only adopts general principles such as validity and reliability, transparency, explainability, accountability, and fairness developed in NIST AI RMF and UNESCO, but extends them into the context of halal integrity (NIST, 2023) (UNESCO, 2021). In the context of halal, trustworthiness requires an additional dimension in the form of Shariah governance, legitimate authority, and human ethical accountability, as AI can support compliance checks and certifications but does not have the normative authority to establish Sharia legitimacy (Sunmola et al., 2025) (Aisyah et al., 2025). Shariah governance ensures the use of AI in accordance with Sharia principles, legitimate authority ensures that normative decisions are made by those who have competence and authority, while human ethical accountability ensures that AI output remains in the mechanism of validation, supervision, and human accountability (Aisyah et al., 2025) (UNESCO, 2021). Thus, the conceptual contribution of this research lies in the development of context-sensitive trustworthy AI for halal integrity, which is AI that is not only technically and ethically trustworthy, but also meets Sharia and institutional legitimacy.

Based on a thematic synthesis of the literature, this study develops a trustworthy AI-enabled halal integrity conceptual framework that describes the relationship between artificial intelligence capabilities, halal integrity maintenance, Sharia governance and human supervision, and ethical accountability. This framework places AI as a supporting technology for verification, traceability, material screening, and risk identification, while normative validation and decisions requiring Sharia assessment remain the authority of competent parties. The conceptual framework is presented in Figure 1.

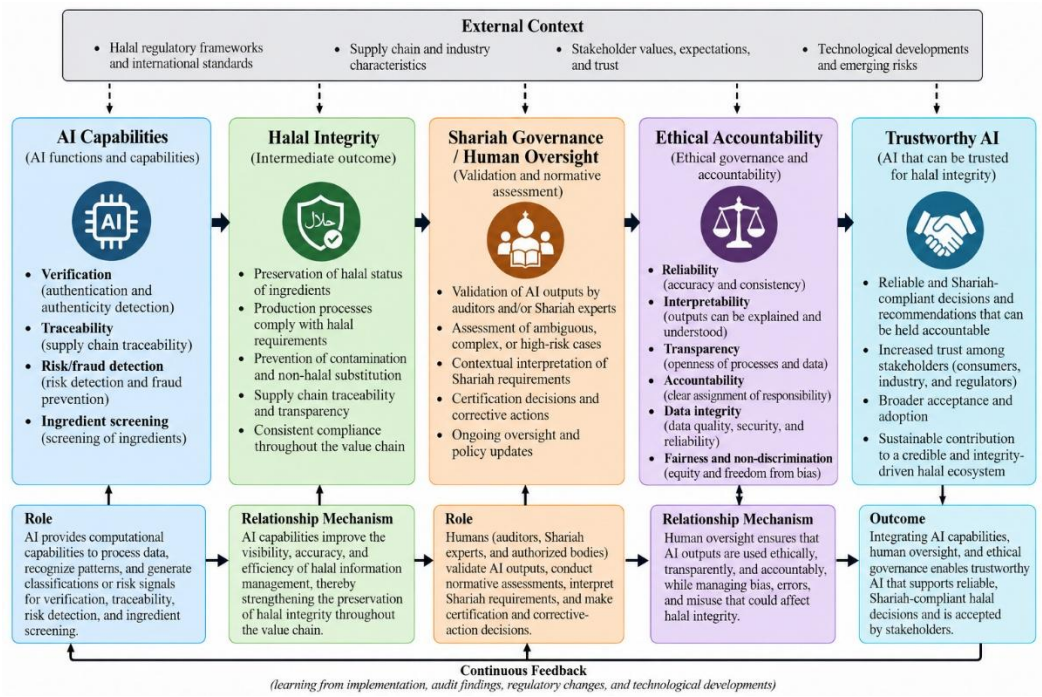


Figure 1. Conceptual Framework of Trustworthy AI-Enabled Halal Integrity

Source: Developed by the author based on a synthesis of literature.

Figure 1 shows that AI capabilities act as an analytical backbone for verification, traceability, material screening, and risk and fraud identification. They support the maintenance of halal integrity, but do not independently establish Sharia legitimacy. Therefore, Sharia governance and human oversight are necessary to validate AI results, assess ambiguous or risky cases, and make decisions that fall within the authority of competent parties. Ethical accountability—which includes reliability, interpretability, transparency, accountability, data integrity, and fairness—governs the use of AI results to be traceable and scrutinized. Feedback from implementation, audits, regulatory changes, and subsequent technological developments can be the basis for continuous improvement. This framework is the result of a conceptual synthesis of the literature and is not intended to be an empirically validated model.

The integration of AI in the halal ecosystem needs to be understood as a socio-technical system, not solely a digitalization project. The success of the technology is not only determined by the capabilities of the algorithm, but also by the quality of the data, user competence, governance, regulations, Sharia authorities, audit mechanisms, and clarity of responsibility. Therefore, the adoption of AI in halal integrity needs to avoid a technology-first approach that places efficiency as the only measure of success. This perspective is in line with the study of AI-powered halal auditing which emphasizes the need to connect AI innovation with Sharia frameworks and regulations (Aisyah et al., 2025) .

Conceptually, this study expands the discussion on halal digitalization by connecting three dimensions that are often discussed separately, namely technological capability, Shariah governance, and human ethical accountability. The available literature has shown the potential of AI in authentication, certification, traceability, and halal supply chains, while the AI ethics literature emphasizes transparency, explainability, fairness, human oversight, and accountability. The synthesis of this research connects the two groups of literature by placing Sharia governance as a mechanism that ensures that improving technological capabilities does not shift the normative authority of humans and legitimate institutions.

Thus, the main findings of the research can be summarized in three propositions. First, AI can strengthen halal integrity through verification, traceability, risk detection, and information analysis. Second, AI cannot stand alone in decisions that require Shariah judgment, because automation is not synonymous with Sharia legitimacy. Third, trustworthy AI-enabled halal integrity requires transparency, explainability, accountability, and data integrity, which are strengthened through human oversight and Sharia governance. This synthesis supports the position that the future of AI-based halal integrity does not lie in the replacement of humans by technology, but rather in the development of a structured relationship between AI capabilities, Sharia authorities, and human ethical responsibility.

Conclusion

The study concludes that artificial intelligence (AI) can serve as a driver of halal integrity technology through verification, tracking, risk detection, and fraud detection. AI can support the identification and analysis of information related to halal materials, suppliers, production processes, certification records, and supply chain activities, thereby strengthening halal assurance and information traceability. However, AI-generated outputs should be positioned as analytical support rather than definitive evidence of halal status.

The study also found that AI cannot independently determine the legitimacy of Sharia. While AI can process information, identify patterns, and generate recommendations, decisions that require Sharia interpretation, contextual assessment, and legitimate religious authority require qualified human oversight. Therefore, automation should not be equated with Sharia legitimacy. Responsible AI integration also requires transparency, explanation, accountability, and data integrity, supported by human review mechanisms, auditability, and institutional accountability.

The main contribution of this research lies in the development of a trustworthy AI-enabled halal integrity conceptual framework that integrates AI technology capabilities, Sharia governance, and human ethical accountability in a single analytical framework. This framework makes it clear that AI functions as a support for verification, tracing, and risk identification, while decisions that require Sharia assessments remain within the authority of competent and authorized parties. In practical terms, this framework can be a consideration for halal certification bodies and auditors in designing procedures for verification, supervision, and escalation of risky or ambiguous cases, as well as for industry players in strengthening data transparency, traceability, and documentation of halal processes. However, because this research is based on a qualitative literature review, the proposed framework has not been tested through system implementation or empirical validation and the research findings cannot be generalized as evidence of the effectiveness of AI in the entire context of the halal industry. Therefore, further research needs to test the framework through case studies, evaluation of AI system performance, and stakeholder-based research involving certification bodies, halal auditors, industry players, technology developers, and Sharia experts to assess the feasibility, applicability, and limits of the use of AI in the halal assurance process.

References

Afdhalia, A. N. (2025). *AI-Augmented Halal Blockchain Integrated with A Qualitypreneur Framework to Enhance Consumer Trust in the Sustainable Halal Industry*. 325–332.

Aisyah, A., Bakar, A., Rafida, N., & Rahim, A. (2025). *Communicating Shariah and*

Regulatory Frames for AI-Powered Halal Auditing. *5*(1). https://doi.org/10.33102/jcicom.vol5no1.138

Ali, H., Aysan, A., & Mesroua, M. (2024). AI in Finance: Applications for Global Finance Institutions and Adaptations for Islamic Finance. In *The Impact of Artificial Intelligence on Societies* (pp. 139–154). Springer Nature Link. https://link.springer.com/chapter/10.1007/978-3-031-70355-3_11

Azwar, A., & Usman, A. H. (2025). *Artificial intelligence in the halal industry : Trends and global research opportunities*. *1*(1), 46–67.

Betz, F. (2021). *Pepperdine Digital Commons From truth to trust : the impact of blockchain traceability on trust in product authenticity by*.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2).

Ellahi, R. M., Wood, L. C., Khan, M., & Bekhit, A. E. D. A. (2025). Integrity Challenges in Halal Meat Supply Chain: Potential Industry 4.0 Technologies as Catalysts for Resolution. *Foods*, *14*(7), 1–32. https://doi.org/10.3390/foods14071135

Fakhlina, R. J., Rahmi, L., & Nurul, F. (2025). *Artificial intelligence as an information analysis process : A systematic literature review*. *11*(2), 480–499. https://doi.org/10.20473/rlj.V11-I2.2025.480-499.Open

Ghalih, M., Chang, C., & Safitri, Y. D. (2025). *Leveraging Artificial Intelligence and Technology for Enhancing Halal Supply Chain Management : A DEMATEL-Based Analysis*. *18*(1).

Gusenbauer, M. (2020). *Which academic search systems are suitable for systematic reviews or meta-analyses ? Evaluating retrieval qualities of Google Scholar , PubMed , and 26 other resources*. *August 2019*, 181–217. https://doi.org/10.1002/jrsm.1378

Haddaway, N. R., Collins, A. M., Coughlin, D., & Kirk, S. (2015). *The Role of Google Scholar in Evidence Reviews and Its Applicability to Grey Literature Searching*. 1–17. https://doi.org/10.1371/journal.pone.0138237

Holzinger, A., Zatloukal, K., & Muller, H. (2025). Is human oversight to AI systems still possible ? *New Biotechnology*, *85*(December 2024), 59–62. https://doi.org/10.1016/j.nbt.2024.12.003

Khan, N., Falahat, M., Ullah, I., Sikandar, H., & Van, N. (2025). Technological innovation for religious compliance: a framework for AI and blockchain implementation in halal food supply chains. *Journal of Islamic Marketing*, *17*(5), 1839–1866.

Lund, B., Orhan, Z., Mannuru, N., & Bevara, R. (2025). Standards, frameworks, and legislation for artificial intelligence (AI) transparency. *AI and Ethics*, *5*, 3639–3655. https://link.springer.com/article/10.1007/s43681-025-00661-4

Mohamed, Y., Rahim, A., & Ma'aram, A. (2020). The effect of halal supply chain management on halal integrity assurance for the food industry in Malaysia. *Journal of Islamic Marketing*, *12*(9), 1734–1750. https://doi.org/https://doi.org/10.1108/JIMA-12-2018-0240

Mohanty, N. (2024). *Role of Artificial Intelligence and Blockchain in Transforming the Operations of Fintech Organisations : An Empirical Study*. *4*(3), 2958–2964.

Nastoska, A., Jancheska, B., & Rizinski, M. (2025). *Evaluating Trustworthiness in AI : Risks , Metrics , and Applications Across Industries*. 1–49.

Nawaz, A., Afzal, A., Khatibi, A., Shankar, A., Madan, H., & Faisal, H. (2025). Role of artificial intelligence in halal authentication and traceability: A concurrent review. *Food Control*, *169*. https://doi.org/https://doi.org/10.1016/j.foodcont.2024.111003

NIST. (2023). *AI Risks and Trustworthiness*. https://airc.nist.gov/airmf-resources/airmf/3-sec-characteristics/

Rahman, M. M., & Razimi, M. S. A. (2023). Halal biotechnology product: halal supply chain compliance and integrity risk. *Innovation of Food Products in Halal Supply Chain Worldwide*. https://doi.org/https://doi.org/10.1016/B978-0-323-91662-2.00016-8

Raihan, M. D. (2024). *Sistem Deteksi Kehalalan Produk Makanan Kemasan Berbasis XAI dengan Integrasi Vision Model dan Web-Retrieval*.

Soon, J. M., Chandia, M., & Regenstein, J. Mac. (2016). Halal integrity in the food supply chain. *Food Supply Chain*, *119*(1), 39–51. https://doi.org/10.1108/BFJ-04-2016-0150

Sunmola, F., Baryannis, G., Tan, A., Co, K., & Papadakis, E. (2025). Holistic Framework for Blockchain-Based Halal Compliance in Supply Chains Enabled by Artificial Intelligence. *Systems*, *13*(1), 1–26. https://doi.org/10.3390/systems13010021

Syaifuddin. (2025). *Sistem Informasi Manajemen Berbasis Artificial Intelligence : Perspektif Keputusan Strategis dan Business Intelligence* (B. Arianto (ed.); 1st ed.). GANESHA KREASI SEMESTA.

Tabassi, E. (2023). *Artificial Intelligence Risk Management NIST AI 100-1 Artificial Intelligence Risk Management*.

UNESCO. (2021). *Recommendation on the Ethics of Artificial Intelligence*. https://www.unesco.org/en/artificial-intelligence/recommendation-ethics?hub=195885

Wahab, A., & Mahdiya, I. (2026). *Reconceptualizing halal industry governance in the digital economy : A maqasid al-Sharia based legal framework*. *1*(2), 152–167. https://doi.org/10.20885/JILDEB.vol1.iss2.art4