ADOPTION OF ANALYTIC NETWORK PROCESS TO STRENGTHEN HALAL INTEGRITY IN THE BROILER CHICKEN SUPPLY CHAIN

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ABSTRACT

This study aims to propose a strategy to strengthen the halal integrity in the food supply chain through investigating and exploring the practice of a traceability system in the broiler chicken supply chain by adopting the Analytic Network Process (ANP) approach. This strategy was developed using an embedded single case study on an end-to-end broiler chicken supply chain in Riau Province, Indonesia. The three distinct data collection methods were in-depth semi-structured interviews guided by the Delphi principle, field observations, and document analysis. Subsequently, the data were meticulously coded and analyzed using NVivo 14 software through template analysis. The development of themes and sub-themes from the final template facilitated the construction of the ANP model, comprising four clusters with a total of 28 criteria. The results indicated that in the business actor and activity cluster, the end consumer criterion was the priority with a weighting value of 0.222. In the stakeholder cluster, the priority was the Halal Inspection Agency (HIA) criterion with a weighting value of 0.178. Meanwhile, the business actors' awareness of halal integrity assurance criterion had a weighting value of 0.217 in the barriers and challenges to adopting a halal traceability

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system. The criterion lean knowledge management process (LKM) for all supply chain actors is the priority for cluster strategy to strengthen halal integrity with weighting value of 0.338. This study showed the importance of upholding halal integrity within food supply chains, which are becoming increasingly complex.

Keywords: halal integrity; traceability; broiler chicken supply chain; ANP

1. Introduction

The halal food industry is flourishing as the second-largest sector in the current economy, following closely behind Islamic finance (Khan et al., 2022). The Future of the Global Muslim Population Report, published by the Pew Research Center's Forum on Religion & Public Life, revealed that in 2020, the worldwide Muslim population stood at 1.9 billion individuals or 24.9%, and the number was predicted to increase by 2030 to 2.2 billion (Indonesian Ministry of National Development Planning, 2018). The rise in the Muslim population has resulted in a concurrent increase in the demand for halal products (Omar, 2011), and in 2021, expenditures on halal food experienced a 6.9% increase from US$1.19 trillion to US$1.27 trillion. Projections suggest a continued increase, with expenditures predicted to grow by 7.0% and attain US$1.67 trillion by 2025, reflecting a four-year CAGR (compounded annual growth rate) of 7.1% (Reuters & Standard, 2022). The trend of increasing demand for halal food by Muslim consumers is also followed by non-Muslim consumers who believe that these foods are healthier.

Islam provides guidelines and regulations on dietary practices, stating adherence to the principles of the faith in the sourcing, processing, and handling of food. These guidelines include various aspects, including slaughtering, nurturing, storage, preparation, display, sanitation, and hygiene (Samori et al., 2014). Halal food must adhere to strict criteria ensuring its compliance with Islamic dietary laws, and refraining from any haram substances or forbidden practices. According to the Holy Qur'an (2:168), the default status of food is halal unless explicitly designated as haram. In this context, haram foods are obtained and derived from prohibited sources, including blood, carrion, pig, permissible animals slaughtered improperly, and intoxicants (Soon, 2017). The concept of halal extends beyond ingredient sourcing to include the entire supply chain, namely food processing, handling, packaging, storage, and transportation.

Muslim consumers should ensure that consumed food strictly adheres to Islamic Sharia law (Hanafiah & Hamdan, 2021) but are often unable to ascertain a product's halal status due to the extensive and intricate nature of the supply chain. Therefore, halal certifications and labels are used to formally satisfy halal requirements and are certified by authorized religious authorities. From a consumer's perspective, the advantages of reliable halal certification can provide convenience in consumption. This saves time by avoiding the need to meticulously check ingredients, understand production methods, and make informed decisions with confidence at the point of purchase. Moreover, halal certification and labels serve as a competitive advantage to guarantee product quality and differentiation (Rafiki & Wahab, 2016).

A product's halal status should be reflected from the upstream to the downstream supply chain to guarantee integrity. According to Alqudsi (2014), transparency is the primary

aspect of enhancing halal integrity, and this is related to traceability, which holds significant importance within the halal supply chain (Khan et al., 2018a). The certification is closely related to halal traceability, serving as the core of the process. Meanwhile, ensuring the halal integrity of products necessitates a meticulous tracing of each item to verify the materials used. Traceability cannot be attributed to an entity since the stakeholders must actively participate and exchange information to uphold halal standards (Rashid & Bojei, 2020). This facilitates tracking the halal status of specific food products at every supply chain stage, fostering transparency and fortifying integrity (Zulfakar et al., 2014).

Indonesia holds the distinction of having the world's largest Muslim population. According to The Royal Islamic Strategic Studies Center (RISSC) report, Indonesia boasts 231.05 million Muslims, comprising approximately 86.7% of the country's population (Karnadi, 2022). Therefore, this study focuses on the broiler chicken supply chain as a subsector of the poultry sector based on the high level of consumption compared to other sources of animal protein. Based on the OECD (Organization for Economic Co-operation and Development) data released in 2018, the proportion of meat consumption in 2017 per capita per year averaged 1.8 kg, 7 kg, and 0.4 kg for beef, chicken, and lamb, respectively. The data from the Central Statistics Bureau (CSB) reported that per capita consumption of chicken meat increased from 80 grams/capita/week to 124 grams/capita/week between 2010 to 2019. Based on CSB data for 2021, the broiler chicken population in 2021 reached 3,107,183,054 birds (Yohanes et al., 2022) and the capitalization of the production with the trade from upstream to downstream increased to IDR 500 trillion.

According to Halal Assurance System Law No.33 2014, broiler chickens are food products that should obtain several forms of halal certification within the supply chain to guarantee halalness. This considers the existence of several Halal Critical Points (HCPs) for broiler chickens, namely the pre-slaughter, slaughter, and post-slaughter stages (Shahdan et al., 2016a). Pre-slaughter includes animal feed, medicine, and farming (Ramli et al., 2020), while the slaughter process necessitates that a healthy and live animal be slaughtered by a Muslim. The procedure involves reciting "In the name of Allah, Allah is the Greatest" and severing all four vessels or tubes, which include the esophagus, trachea, and external jugular veins (Soon et al., 2017). Post-slaughter includes processing, transporting, packaging, warehousing, and handling. The Halal Product Assurance Administration Board (BPJPH) stated that the principle of traceability is a concept existing in halal product assurance, and this principle has been applied in halal certification. Halal certification can be applied as part of the halal traceability system due to comprehensive tracing and tracking capabilities, which include all aspects of the product from upstream to downstream. Even though an increasing number of studies have examined traceability and halal integrity, only a few have explored halal in the broiler chicken supply chain. Hence, the purpose of this study is to:

1. Investigate and explore the practice of traceability systems in the broiler chicken supply chain.
2. Propose a strategy to strengthen halal integrity within the supply chain by adopting an Analytic Network Process (ANP) approach.

2. Literature review

2.1 Halal food supply chain management

The supply chain includes all entities that directly or indirectly play a part in fulfilling customer demand (Kadir et al., 2016). Additionally, it serves as a network among organizations working domestically or globally to ensure the flow of materials and information between customers and suppliers, aiming to minimize cost while maximizing speed. A supply chain can be described as a timeline of material movement from one supplier to an end customer that includes processes such as manufacturing, purchasing, transportation, warehousing, planning, and service. This process includes people, activities, information flows, and product movement from suppliers to target customers (Fernando et al., 2021).

Implementing halal principles in food supply chain management evolves into Halal Food Supply Chain Management (HFSCM), which encompasses the entire journey from origin to consumption. HFSCM incorporates halal concepts to meet consumer requirements by coordinating the efforts of all parties in production and distribution. These activities consist of procurement, product handling, warehousing, transportation, order management, and inventory management, and adhering to Sharia guidelines (Mohamed et al., 2020). Moreover, the approach to the food supply chain also accommodates the "*toyyib*" aspect, ensuring the engagement of stakeholders in fair trade practices, ethical business practices, sustainability, humane farming, as well as corporate social responsibility values. HFSCM includes controlling the flow of information, capital, and material through strategic coordination and collaboration among stakeholders, aimed at enhancing the supply chain's performance (Khan et al., 2018a).

2.2 Halal integrity

Halal integrity entails providing comprehensive information about a product's status and ensuring compliance with halal requirements (Soon et al., 2017). Additionally, the variable indicates a product's halal status across the supply chain, free from non-halal activities (Zulfakar et al., 2012). Ensuring halal integrity presents challenges due to the involvement of different companies across various stages of production, processing, and transportation. According to Alqudsi (2014), preserving the halal integrity of the supply chain poses a challenge due to the ongoing need for monitoring and the allocation of resources such as capital and trained personnel. Nevertheless, the increasing demand from consumers and the proactive measures taken by producers to tap into the expanding markets drive the need to uphold the halal status of food.

The integrity of halal products should be guaranteed throughout the supply chain, from upstream to downstream (Tieman, 2011). Nevertheless, certain foods have lost their halal status due to dishonest suppliers who fail to adhere to Sharia law, despite their crucial role as providers of raw materials, which is fundamental to maintaining integrity (Khan et al., 2019). Tieman et al. (2012) emphasized the significance of procuring raw materials in the model. Halal suppliers are responsible for verifying that the raw materials supplied adhere to Sharia law standards (Ali et al., 2017). Hence, the careful selection of suppliers significantly influences the maintenance of halal food integrity. This is because the quality of food relies heavily on the products and the integrity of the suppliers (Ali et al., 2017). There is a pressing need to investigate and disseminate the latest advancements pertaining to dependable suppliers adhering to halal principles in accordance with Sharia

law (Handayani et al., 2022). A global halal supply chain is obtained when integrity is maintained regardless of the country (Soon et al., 2017).

2.3 Halal traceability

Traceability refers to the ability to access relevant information about a specific entity throughout its entire lifecycle, aided by documented identification methods (Olsen & Borit, 2013). Moreover, it furnishes a continuous stream of information regarding raw material sources, processes, logistics, and product locations throughout the supply chain. This variable additionally functions as a tracking and communication mechanism to guarantee the availability of information. The traceability of halal products places an added emphasis on transparency within the supply chain, in conjunction with its primary goals of accurately documenting history and location. Enhanced transparency in halal practices contributes to consumer confidence in the authenticity of products due to the extensive disclosure of information regarding raw materials, production methods, storage conditions, transportation logistics, and retailing procedures (Khan et al., 2018b). In this context, halal traceability in poultry covers the pre-slaughter, slaughter, and post-slaughter stages (Shahdan et al., 2016b), as well as uncontaminated healthy rearing environment facilities (Shuib et al., 2021). Transparency fosters heightened consumer confidence by providing extensive information regarding raw materials, storage, production processes, transportation, and retail operations. Meanwhile, an effective traceability system can mitigate the risk of contamination, as well as the use of non-halal raw materials and processes (Khan et al., 2018b).

A traceability plan should be crafted to attain specific objectives, including regulatory compliance, increasing product safety and quality control, enhancing organizational efficiency, productivity, and profitability, as well as fulfilling customer demands (Lavelli, 2013). Effective communication and management among connections within the supply chain are crucial components of an efficient traceability system (Yusaini et al., 2016). Additionally, traceability comprises two fundamental facets, namely tracing and tracking. Tracing involves the capability to trace food ingredients back through the production chain from producers to end-users, as well as to the suppliers. The primary aim is to show the product's history, thereby facilitating tasks such as identifying potential sources of cross-contamination. In contrast, tracking includes following the trajectory of individual units or groups of products downstream through the supply chain and transitioning among trading partners. In halal products, traceability is implemented to enhance transparency and increase consumer confidence by providing greater insights into production processes, food safety controls, and other pertinent factors. Therefore, a seamless flow of information throughout the supply chain can elevate the actual level of halal integrity in food products (Zailani et al., 2010).

2.4 Analytic Network Process (ANP)

Thomas L. Saaty developed the Analytic Network Process (ANP), regarded as a broader form of the Analytic Hierarchy Process (AHP) (Khan et al., 2020). The ANP addresses more intricate relationships, interdependencies, and situations while also offering feedback among the elements within the hierarchy. The applications extend across diverse fields including social sciences, environmental studies, and engineering to offer a deeper exploration of uncertainty and risk (Sipahi & Timor, 2010). Furthermore, the ANP develops a particular problem into a network rather than converting it into a hierarchical

process. This occurs due to the connections between decision clusters and elements via network links (Chemweno et al., 2015).

The inclusion of interactions and dependencies between higher-level and lower-level elements renders many decision problems unsuitable for hierarchical structuring. The importance of the criteria determines the alternatives in the hierarchy and criteria. An individual might instinctively prefer a stronger but less visually pleasing option when confronted with two bridges possessing strength with different aesthetic appeals unless the evaluation criteria are contextualized within the attributes. In this context, strength is assigned a lesser value, and appearance is deemed more significant, even though the two bridges are structurally strong (Saaty & Vargas, 2006). The aim of the ANP is to identify the optimal alternative by considering multiple decision criteria. The decision is performed by pairwise comparisons of components, ultimately resulting in the selection of an alternative in decision-making scenarios (Ayag & Özdemir, 2009). Additionally, the ANP is employed to examine the relationships among provided factors, integrate feedback, as well as illustrate the interdependent connections among decision attributes and alternatives (Saaty & Vargas, 2006).

The ANP approach is widely regarded as an ideal choice for developing selection problems for various situations. The application is well-suited for addressing complex decision problems involving multiple criteria. Considering the complexity of real-life decision problems, it becomes essential to weigh the trade-offs between intangible and tangible decision criteria. To accommodate these trade-offs, the ANP enables decision-makers to articulate preferences between elements via the reciprocal pairwise comparison process, employing Saaty's fundamental scale. Furthermore, the decision-making process ensures consistency by computing the CR (Consistency Ratio) (Chemweno et al., 2015). The method also takes into account the interdependencies between clusters and decision elements within the ANP network structure. In this context, the ANP utilizes the eigenvalue method as the main technique for lowering priorities (Saaty, 2004b). The application calculates intricate relationships between decision elements by substituting hierarchical structures with networks. Furthermore, it encompasses all the advantageous aspects of the AHP, such as flexibility, simplicity, simultaneous usage of qualitative and quantitative criteria, as well as the capability to assess consistency in scoring. The ANP also views each problem as a network comprising criteria, sub-criteria, and alternatives. The elements within a network can establish relationships with each other, as feedback and interconnections are feasible between clusters (García-Melón et al., 2008).

3. Methodology

This research was developed using an embedded single case study on an end-to-end broiler chicken supply chain in Riau Province, Indonesia. A case study is an empirical method used to investigate and explore the halal traceability system in ensuring halal integrity. A total of three data collection methods were employed, including in-depth semi-structured interviews guided by the Delphi principle, field observations, and document study. Subsequently, the RAND Corporation provided the simplest definition of the Delphi method as "generating and refining group assessments". The method facilitated structured group communication to collect a consensus of expert opinions when facing intricate problems, costly efforts, and uncertainty (Grime & Wright, 2016).

The main data source for the Delphi method was usually a panel of experts (Aldrighetti et al., 2021). Rowe and Wright (2001) stated the key principles for the selection of a group of experts and emphasized the importance of selecting individuals with pertinent domain knowledge, ensuring diversity within the group, and ideally comprised of several experts ranging between 5 and 20 individuals. In this study, the experts were selected by adopting the quadruple helix (QH) model to create interaction among the university, industry, government, and society. Moreover, the model integrated the roles of entrepreneurs, academics, civil society, and government into creative and knowledge-based activities (Okfalisa et al., 2021). This study enlisted the expertise of nine individuals who represented various sectors including government, academia, industry, and civil society. These experts possessed specialized knowledge and experience relevant to the halal sector and the broiler chicken supply chain.

The interview technique used a one-to-one approach, and was conducted individually with each expert to ensure a focused gathering of knowledge and opinions pertinent to their respective expertise. This approach was implemented to enhance critical and creative thinking among the participants. Meanwhile, interviews were conducted both offline and online, using the Zoom application. In this context, field observations were performed by observing key supply chain actors, including farm owners and chicken slaughterhouses. Short interviews were also conducted during the observations to supplement the data gathered. Moreover, a document study was carried out to acquire secondary data not accessible through field observations or in-depth semi-structured interviews. This included written documents and audio-visual materials such as company reports, statutory regulations, articles from online publications, and official websites. In this study, the research technique and procedure flow is shown in Figure 1.

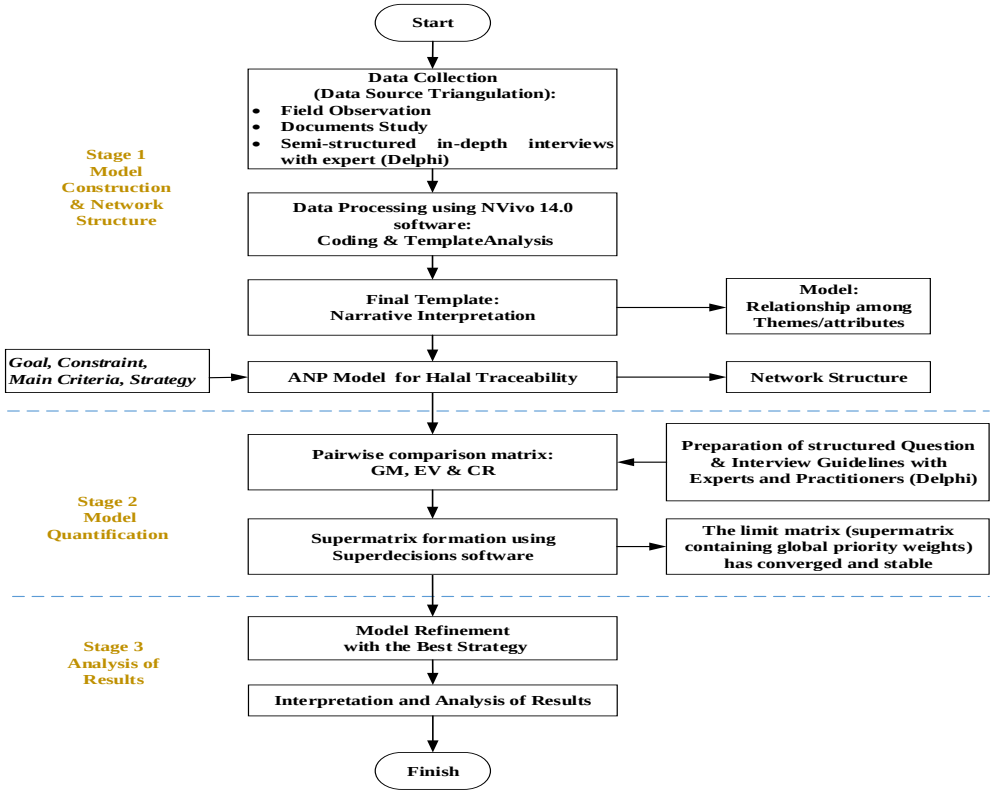

Figure 1 Research technique and procedure

The data obtained from in-depth semi-structured interviews, field observations, and the document study were in the form of words. In NVivo 14 software, all data were coded and analyzed using template analysis. NVivo is software for the development, support, and management of qualitative data analysis projects. Quantitative and qualitative data can be efficiently and effectively investigated using the software. In this context, codes are constructs created to symbolize attributes in interpreting the meaning of each data for pattern detection, categorization, theory building, and other analytical processes. Data coding is carried out by intensive reading to determine the classification (Priyatni et al., 2020).

Template analysis is a method used for organizing and analyzing qualitative data thematically. This type of thematic analysis prioritizes hierarchical coding while balancing a relatively high degree of structure in analyzing textual data with the flexibility of adapting to the necessities of a specific study (Brooks et al., 2015). The essence of template analysis lies in producing a list of codes representing the themes in the textual data. The template is structured to represent the relationships between themes (Brooks & King, 2012). The analysis determines several themes before the process, which are referred to as “a priori” themes. This occurs because the study commences with the assumption that specific aspects of the phenomenon investigated warrant analysis. A priori themes can also be subjected to redefinition or deletion when proven to be ineffective at characterizing the data (Brooks & King, 2012).

After obtaining the final template, narrative interpretation was carried out. The results were model constructs with criteria and sub-criteria from the themes and sub-themes. In this context, an ANP model was constructed to transform a topic network structure. In template analysis, a problem should be translated into a logical system, such as a network, based on the narrative interpretation.

Before formulating a pairwise comparison matrix and determining priority vectors, the ANP model should be constructed (Saaty, 2004; Cheng et al., 2005; Kheybari et al., 2020). At this stage, structured interviews are conducted using guided questions with experts to provide an assessment expressed in the form of pairwise comparisons between the elements within the network. Similar to pairwise comparison performed in the AHP, decision elements in each cluster are compared pairwise. Meanwhile, comparisons are also made between clusters regarding their role and effect in achieving objectives, as well as the interdependencies among the criteria within each cluster. The effect of criteria on each other can be elucidated through the eigenvector. The relative importance of the elements is evaluated using the Saaty nine-point scale, as per the assessment scale outlined in Table 1. The pairwise comparison process utilizing actual measurements for the elements compared produces a consistent reciprocal matrix as shown in Equation (1):

$$\mathrm{A} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{bmatrix} \quad (1)$$

The next step is calculating the eigenvectors (priority weights) of each developed matrix, using Equation (2):

$$Aw = \lambda_{max}\, w \quad (2)$$

where A represents the pairwise comparison matrix of the criteria, w denotes the eigenvector, and λ_{max} represents the largest eigenvalue. Typically, a geometric mean approximation is employed to compute the eigenvector w.

Table 1
Fundamental scale of absolute numbers

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated important	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
Rationale	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Source: (Saaty & Vargas, 2006)

The consistency ratio (CR) of each matrix is measured to assess the pairwise comparisons using Equations (3) and (4). Saaty (1994) determined three levels of acceptable CR values, namely 0.05, 0.08, and 0.1 for a 3 by 3, 4 by 4, and other matrices, respectively (Cheng et al., 2005). In another article, Saaty (2013) stated that a pairwise comparison is deemed acceptable when the CR value is less than 0.1 (Elhidaoui & Kota, 2023).

$$CR = \frac{CI}{RI} \tag{3}$$

$$CI = \frac{\lambda_{max-n}}{n-1} \tag{4}$$

where CI represents the Consistency Deviation Ratio (Consistency Index) and n denotes the matrix order. RI (Random Index) is derived from an experiment conducted by the Oak Ridge National Laboratory and refined by the Wharton School, as illustrated in Table 2.

Table 2
Random Index Value

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: (Yohanes, 2014)

The next step is Super-matrix formation and deriving global priority weights (Chemweno et al., 2015). The formation of a super-matrix with eigenvectors from each matrix is also known as a sub-matrix. A super-matrix comprises sub-sub matrices that include a set of relationships between two levels within the model. The effect of elements within the network on other elements can be represented in a super-matrix (Saaty & Vargas, 2006). To achieve priority in a system with interactions, the internal interest vectors should be included in certain columns and the final step is to select the best option. Meanwhile, the final weights of the considered alternatives can be obtained from the column within the finite super-matrix. In this context, the alternative with the highest weight is regarded as the primary choice (Kheybari et al., 2020).

4. Results and discussion

4.1 Final template and ANP model

The results from stage 1 are the ANP model construction and network structure. On the report of the coding process and template analysis using NVivo 14 software, a final template was structured as shown in Figure 2. This reports the relationships among themes used as constructs and initial criteria for the ANP model.

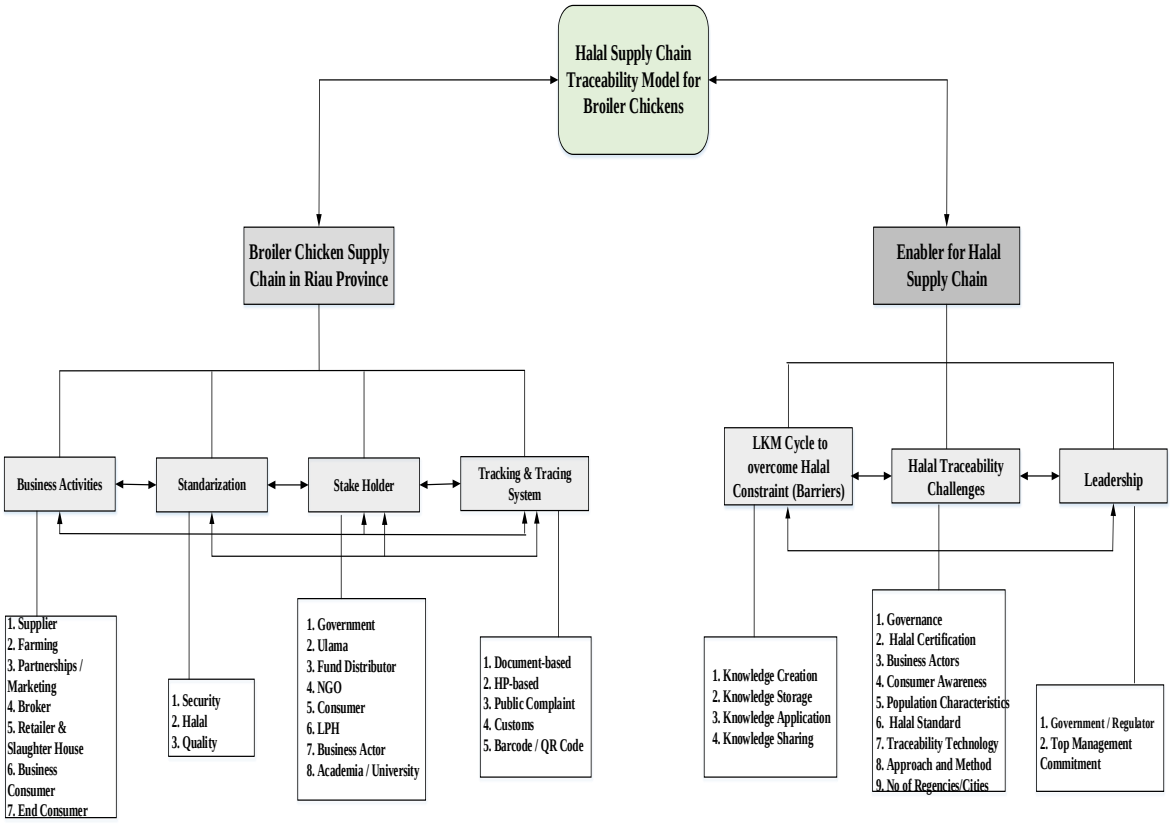

Figure 2 Coding and template analysis result

The case study of the broiler chicken supply chain in Riau Province has critical, unique, and special characteristics. From the product context, broiler chickens have the characteristics of perishable foods, such as limited shelf life, uncertain demand, and requiring special transportation conditions. From the context of halal food, the supply chain has many HCPs which challenge every actor located in almost the entire complex supply network and the potential for deterioration. The supply chain in Riau Province has a unique and critical pattern for broiler chickens as shown in Figure 3.

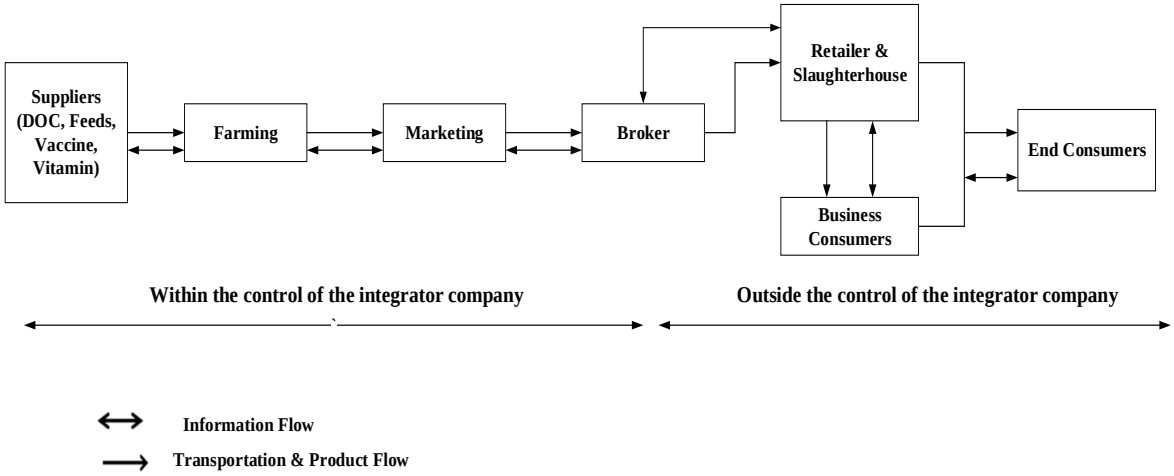

Figure 3 Broiler chicken supply chain pattern in Riau Province

According to the pattern, the supply chain consists of upstream and downstream. The upstream supply chain is managed and controlled by an integrator company, unlike the downstream supply chain. Broiler chickens produced from the integrator company's partner farms are distributed to retailers that function as slaughterhouses. In Riau province, there are no large-scale slaughterhouses or large-scale chicken meat processing industries. Integrator companies as business actors in the upstream have a very big role as suppliers of Day-Old Chicken (DOC), chicken feed, as well as animal pharmaceutical supplies such as medicines, vaccines, and vitamins.

Most of chicken farms in Riau Province are partners within the integrator company. Many independent farms are switching to partner systems to obtain certainty of supply and distribution or sale of the chickens produced. In the downstream of the supply chain, chickens produced from farms are distributed by brokers to retailers. Meanwhile, chicken retailers in the province have unique characteristics of also functioning as Chicken Slaughterhouses (CSH). The CSH businesses operating in Riau are Small and Micro Enterprises (SMEs). From the CSH, chickens are distributed to business consumers such as restaurants, hotels, bakeries, street food vendor and household customers.

To ascertain the presence of HCP and evaluate the potential for disruptions to animal welfare within each business activity, a systematic mapping process was conducted. The mapping was conducted utilizing the SCOR (Supply Chain Operations Reference) model version 12.0. This model facilitates the comprehensive mapping of current business activities or processes referred to as the "current state" for business actors, based on the categories of Plan, Source, Make, Deliver, Return, and Enable business activities. The determination of HCP and assessment of animal welfare standards are conducted through expert judgment. The mapping exercise showing HCP and assessing animal welfare within each business activity is presented in Table 3. HCP and concerns related to animal welfare are identified across the entire supply chain. However, particular attention is given to the CSH as the most critical point since the CSH is a SME, with only a limited number possessing halal certification. SOPs and certifications are absent as standard benchmarks, along with a deficiency in explicit knowledge guiding operational processes.

Based on data sourced from the Riau Province Halal Product Assurance Administration Board (BPJPH) concerning CSHs in the region, only 12 have obtained halal certification among the thousands of SME-scale chicken slaughterhouses.

Table 3
Mapping of HCP and animal welfare in the supply chain

Business Actors	**Activities**	**HCP**	**Animal Welfare**	**Explanation**	**Type of Knowledge to cope with HCP & Animal Welfare**
Supplier: Feed Factory	Plan	√		Formula planning, % of minor materials	ISO 22000:2018 Food Safety Management System (Explicit Knowledge)
	Source	√		Food additives, vitamins, minerals	
	Make				
	Deliver				
	Return				
	Enable				
Supplier: Breeding Farm	Plan				
	Source				
	Make		√	Growing and Laying Period: density	Good Breeding Practices Certification (Explicit Knowledge)
	Deliver				
	Return				
	Enable				
Supplier: Hatchery Farm	Plan				
	Source				
	Make		√	Process of putting DOC into the box	Indonesian National Standards (SNI) Certification (Explicit Knowledge)
	Deliver	√		Transportation to deliver DOC to the farm	
	Return	√		Defect DOC	
	Enable				
Farming	Plan	√		DOC arrival (number, time, place)	Good Farming Practices Certification & Biosecurity System (Explicit Knowledge)
	Source				
	Make	√		Cage cleaning; Density control	
	Deliver	√	√	Transportation to deliver chickens	
	Return	√		Dead chickens	
	Enable				
Marketing	Plan				
	Source				
	Make				
	Deliver				
	Return				
	Enable				
Broker	Plan				
	Source				
	Make		√	Prepare the cage as a temporary warehouse	Biosecurity System (Explicit Knowledge)
	Deliver	√		Trucking to transport chickens	
	Return				
	Enable				
Retailer & Slaughterhouse	Plan				
	Source				
	Make	√	√	Storing chickens in a temporary warehouse; slaughtering process; process after slaughtering; sanitation and hygiene	No Standardizations (No SOP) (Tacit Knowledge)
	DeliverReturn	√		Transportation to send chicken meat to consumers	
	Enable				

Chicken is inherently considered halal, but the status can shift to haram when the slaughtering process deviates from Islamic law. The CSH serves as a supplier of chicken meat for public consumption, and acquiring a certificate can significantly enhance the quality of safe and healthy meat. A halal slaughterhouse necessitates support in the form of appropriate raw materials, skilled slaughterers, and production processes or equipment free from contamination by non-halal elements. Moreover, ensuring halal practices extends to packaging processes and transportation for distribution to consumers. Field investigations and concise interviews with owners of halal-certified slaughterhouses show that the desire to obtain a halal certificate is based on requests or requirements of business consumers. A halal certificate or label serves as an emblem of assurance regarding product standardization, signifying adherence from raw materials to the final product. This adheres to consistent standards to ensure that each point in the supply chain maintains uniform certification standards.

The presence of many CSHs that are not halal certified indicates chicken meat is consumed that is not assured to be halal due to the inability to trace the chicken through a halal certificate. The slaughtering phase has particular significance due to the distinction between halal and non-halal meat (Soon et al., 2017). The existence of only 12 CSHs with halal certificates poses a predicament to ensuring the integrity of chicken meat, considering the increased number of CSHs operating in the region. Indonesia's Halal Assurance System Law explicitly mandates that all products, specifically food and beverages, slaughter services, raw materials, food additives, and auxiliary ingredients, must be halal-certified by October 17, 2024. Therefore, the current situation shows the urgency of the need to enhance compliance and enforcement measures to uphold halal standards within the poultry supply chain, specifically broiler chickens.

After the problem was identified, solutions and strategies were carried out in the first stage of decomposition (Widiastuti et al., 2021). A strategy is needed to improve and strengthen halal integrity and the formulation was carried out by adopting the ANP. The technique is frequently employed to examine the relationships among the provided factors, incorporate feedback, as well as illustrate the interdependent relationships between decision attributes and alternatives (Demirkesen & Bayhan, 2020). Based on the final template and the existing problem, four clusters are the main focus to strengthen halal integrity, including business actors and business activities, stakeholders, barriers and challenges to adopting a halal traceability system within the supply chain and strategy to fortify halal integrity in the broiler chicken supply chain in Riau province. The four clusters were obtained from the analysis template and narrative interpretation.

a. Identification of business actors and their business activities in the broiler chicken supply chain.

In this case, there are seven business actors and the activities are as follows:

(1) Supplier (P1)
(2) Farming (P2)
(3) Partnership & Marketing (P3)
(4) Broker (P4)
(5) Retailer & Slaughterhouse (P5)
(6) Business Consumer (P6)
(7) End Consumer (P7)

b. Identification of stakeholders in the broiler chicken supply chain.

In this case, there are eight stakeholders in the supply chain as follows:

(1) Government (S1)
(2) Ulama (S2)
(3) Funding Institutions (S3)
(4) Non-governmental organizations (NGO) (S4)
(5) Society/Consumers (S5)
(6) Halal Inspection Agency (HIA) (S6)
(7) Business Actors (S7)
(8) University or Academia (S8)

c. Identification of barriers and challenges in adopting a halal traceability system in the supply chain (HT).

In this case, there are eight barriers as follows:

(1) The governance of the halal assurance system is not yet optimal (HT 1)
(2) Halal certification is considered complicated and expensive by business actors (HT 2)
(3) Business actors' awareness of halal integrity assurance is still low (HT 3)
(4) Consumers' halal awareness is still low (HT 4)
(5) Differences in business scale and business ownership (HT 5)
(6) The investment cost of traceability technology is still considered expensive (HT 6)
(7) Technical obstacles to the use of halal traceability technology among some business actors (HT 7)
(8) Too many districts/cities make it difficult to disseminate information about halal (HT 8)

d. Identification of strategy to strengthen halal integrity in the broiler chicken supply chain in Riau Province.

Several strategies were formulated to overcome the barriers and challenges in adopting a halal traceability system in the supply chain as follows:

(1) Efficient knowledge management processes (Lean Knowledge Management) in all business activities in supply chain businesses (ST 1)
(2) Selection of halal traceability technology with affordable investment costs for all business actors, ease of use, and a good level of application security (ST 2)
(3) Rewards and penalty for business actors who comply or do not with halal assurance system regulations (ST 3)

(4) Commitment to implement halal assurance from top management of business actors (ST 4)
(5) Strengthening the government's role as regulator of the halal assurance system (ST 5)

The ANP model for halal traceability is shown in Figure 4 and the relationship is reported by arrows and circles (loops). In the model, the elements not included within arrows represent source components, depicted by destinations. Each cluster forms a two-way cycle because the clusters provide feedback to each other. The other relationships represent dependencies between components known as outer-dependent.

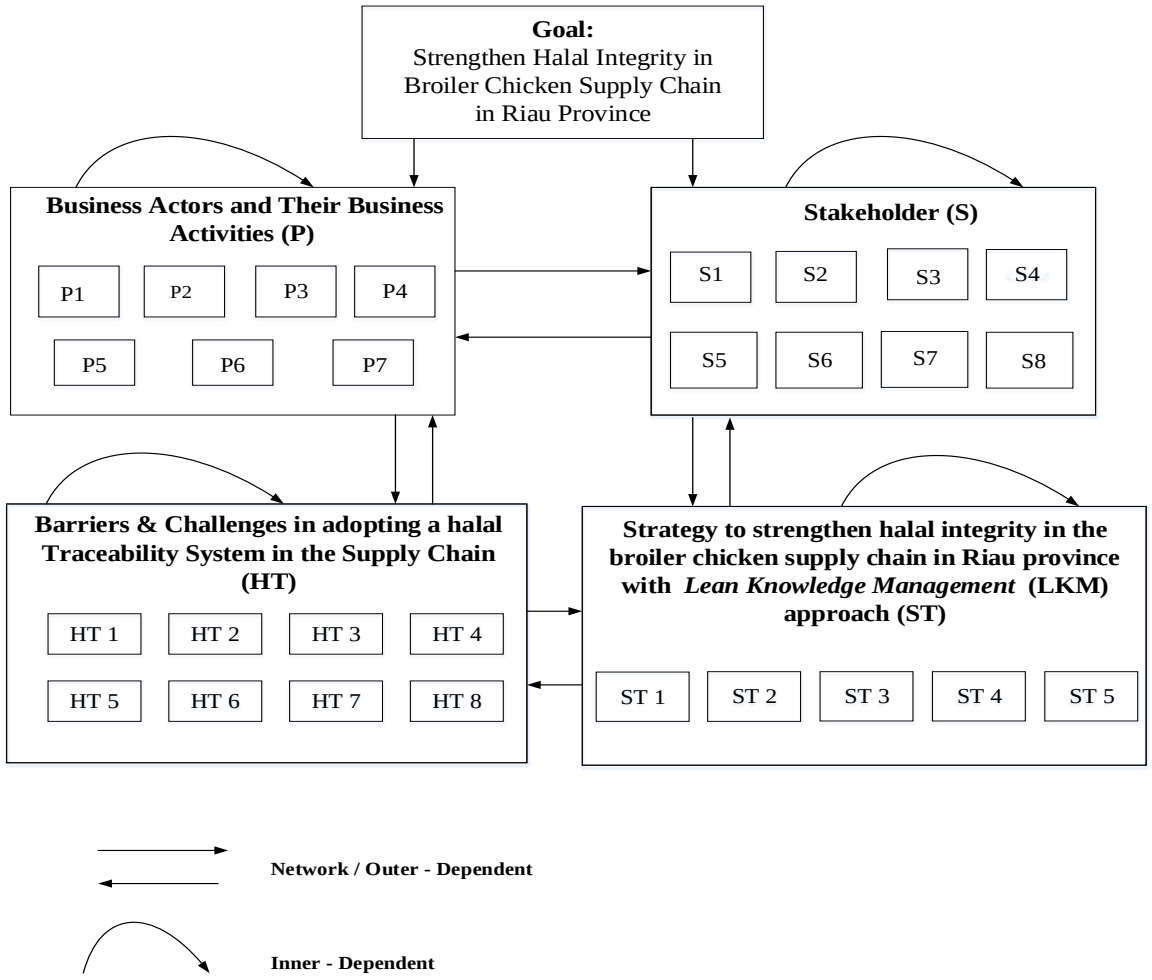

Figure 4 ANP model for halal traceability

4.2 ANP results

The ANP model to strengthen halal integrity in the broiler chicken supply chain was evaluated in stages 2 and 3. Pairwise comparisons in the ANP are carried out by comparing the level of importance of decision elements in each cluster. The clusters are

also compared based on the role and influence they have in achieving the objectives as well as the interdependence between the criteria. Additionally, the influence of criteria on each other can be given through eigenvectors.

The data from the answers filled in by the participants are recapitulated using the MS Excel program, with formulas developed to compute the relative weights of matrices and the CR. A rerating of the questionnaire is necessitated when a matrix yields an unacceptable CR value. The concept of pairwise comparison can be explained to those completing the pairwise comparison to address the consistency of ratings. Table 4 shows the CR values for the inter-cluster comparison for all clusters and criteria. From this table, the pairwise comparison is deemed acceptable when the CR value is less than 0.1.

Table 4
Pairwise Comparison and CR value

No	Pairwise Comparison	CR Value
1	Inter-cluster Comparison	0.047
2	Comparison between Supply Chain Actor criteria	0.036
3	Comparison between Stakeholder criteria	0.077
4	Comparison between criteria Barriers and Challenges in adopting a Halal traceability system in the supply chain	0.037
5	Comparison Between HTs to be completed in P2	0.015
6	Comparison of ST applied to P2 to deal with HT	0.036
7	Comparison Between HTs to be completed in P4	0.007
8	Comparison of ST applied to P4 to deal with HT	0.032
9	Comparison Between HTs to be completed in P5	0.032
10	Comparison of ST applied to P5 to deal with HT	0.038
11	Comparison Between HTs to be completed in P6	0.019
12	Comparison of ST applied to P6 to deal with HT	0.075
13	Comparison Between HTs that must be completed in S1	0.04
14	Comparison of ST applied to S1 to deal with HT	0.098
15	Comparison Between HTs to be completed in S2	0
16	Comparison Between HTs to be completed in S3	0
17	Comparison between ST applied to S3 to deal with HT	0
18	Comparison Between HTs to be completed on S4	0
19	Comparison Between HTs to be completed on S6	0
20	Comparison Between ST applied to S6 to deal with HT	0
21	Comparison Between HTs to be completed on S7	0.039
22	Comparison of ST applied to S7 to deal with HT	0.018
23	Comparison Between HTs to be completed on S8	0.076
24	Comparison Between ST applied to S8 to deal with HT	0
25	Comparison between ST applied to deal with HT 1	0
26	Comparison between ST applied to deal with HT 2	0.004
27	Comparison between ST applied to deal with HT 3	0.093
28	Comparison between ST applied to deal with HT 4	0
29	Comparison between ST applied to deal with HT 5	0.014
30	Comparison between ST applied to deal with HT 6	0
31	Comparison between ST applied to deal with HT 7	0
32	Comparison between ST applied to deal with HT 8	0.082

A super-matrix was configured to show the effect of elements within the network on each other. In this study, the formation of the super-matrix was facilitated through the utilization of Super Decisions software. Pairwise comparison matrices can be input into the software to ascertain the weight of each index. Table 5 presents the super-matrix, which comprises eigenvectors linked to the four clusters. The super-matrix includes the eigenvector resulting from the matrix comparing the four clusters of the decision problem. Additionally, the super-matrix incorporates eigenvectors derived from the matrices reflecting the interdependent influences among the four clusters and twenty-eight criteria.

The concluding stage includes determining the priority among clusters to fulfill the model's objectives. In the business actor and activity cluster, experts assigned the highest importance to the end consumer criterion, with a weighting value of 0.222 or 22.2%. For the stakeholder cluster, the HIA criterion was identified as the most crucial by experts, with a weighting value of 0.178 or 17.8%.

Table 5
Alternative priority weighting

Cluster	**Criteria**	***Normalized By Cluster***	***Limiting***	***Rank***
Business actors and their business activities (P)	Supplier (P1)	0.109	0.017	6
	Partnership & Marketing (P2)	0.121	0.019	4
	Farming (P3)	0.161	0.025	3
	Broker (P4)	0.116	0.018	5
	Retailer & Slaughter House (P5)	0.183	0.028	2
	Business Consumer (P6)	0.088	0.014	7
	End Consumer (P7)	**0.222**	**0.034**	**1**
Stakeholder (S)	Government (S1)	0.164	0.011	2
	Ulama (S2)	0.151	0.010	3
	Penyalur Dana (S3)	0.074	0.005	7
	NGO (S4)	0.142	0.009	5
	Consumer (S5)	0,073	0.005	8
	HIA (S6)	**0.178**	**0.012**	**1**
	Business Actor (S7)	0.144	0.010	4
	University / Academia (S8)	0.075	0.005	6
Barriers and challenges in adopting a halal traceability system in the supply chain (HT)	The governance of the Halal Assurance System has not been optimal (HT1)	0.120	0.026	5
	Halal certification is considered complicated and expensive by business actors (HT2)	0.173	0.038	2
	Business Actors' Awareness of Halal Integrity Assurance is still low (HT3)	**0.217**	**0.047**	**1**
	Consumers' Halal Awareness is still low (HT4)	0.155	0.034	3
	Differences in business scale and business ownership (HT5)	0.079	0.017	6
	The cost of investing in technology is still considered expensive (HT6)	0.132	0.029	4
	Technical obstacles to the use of halal traceability technology among some business actors (HT7)	0,085	0,018	7
	Too many districts/cities make it difficult to disseminate information about halal (HT8)	0,039	0,009	8
Strategy to strengthen halal integrity in the broiler chicken supply chain in Riau province with *Lean Knowledge Management* (LKM) approach (ST)	**Lean knowledge management process for all supply chain actors (ST1)**	**0.338**	**0.190**	**1**
	Selection of halal traceability technology with affordable investment costs for all business actors, easy to use, and a good level of application security (ST2)	0.146	0.082	4
	Rewards and punishments for business actors who comply with regulations or not with a halal Assurance system (ST3)	0.132	0.074	5
	Commitment to implement halal guarantees from top management of business actors (ST4)	0.190	0.107	3
	Strengthening the government's role as regulator of the halal assurance system (ST5)	0.194	0.109	2

In the barriers and challenges to adopting a halal traceability system, the "business actors' awareness is low" is the highest priority criterion with a weighting value of 0.217 or 21.7%. In the strategy to strengthen halal integrity in the broiler chicken supply chain cluster, Lean Knowledge Management (LKM) process is the most priority criterion with a weighting value of 0.338 or 33.8%.

4.3 Discussion

Lean and knowledge management (KM) alliances could be a powerful management tool (enabler) to deal with wasteful knowledge (Anggraini et al., 2024). LKM means efficient knowledge management which eliminates all forms of waste interfering with the knowledge management process. Waste is characterized as any human activity or action that consumes resources without generating value (Klein et al., 2023a). According to Forsgren (2022), LKM includes collecting and sharing only related knowledge that helps organizations work safely, effectively, and efficiently. Moreover, Sangari (2015) and Batista et al. (2019) reported that the basic patterns were knowledge creation, storage, application, and sharing. Regarding knowledge, several types of waste occur in the process including underutilized people (Douglas et al., 2015) or waste of talent (Kazancoglu & Ozkan-ozen, 2019), unnecessary bureaucracy (Klein, et al., 2023b), loss of knowledge (Durst & Zieba, 2019), waste of explicit knowledge, retention of tacit knowledge (Alshamsi & Ajmal, 2019), over or under specialization (Klein, et al., 2023b), unclear communication (Douglas et al., 2015), and a classic type of waste during the KM process, namely over processing (Ohno, 1988).

Even though the LKM process may seem straightforward in theory, the implementation often experiences challenges and disruptions (Ferenhof et al., 2015). In the context of supply chain management, the LKM process increases cooperation and coordination among various partners and actors, aiming to enhance knowledge-based relationships and improve operational performance (Kalogeraki et al., 2018). However, in this study, LKM is confronted with complexities due to the participation of seven distinct business actors across the supply chain with varying ownership statuses, scales, cultures, and knowledge capabilities. This multi-faceted landscape renders the process far from straightforward, particularly compared to the execution within a single organization. Meanwhile, experts have identified the end consumer as the most critical business actor. High halal awareness among end consumers compels upstream actors to assume greater responsibility in ensuring product guarantees by disclosing the status information and compliance with requirements. Halal traceability transcends individual interests and responsibilities but represents a value chain effort aimed at enhancing business processes at every stage. Furthermore, the ANP results are similar to the foundational theory showing the assertions. Based on expert opinions through semi-structured in-depth interviews, the results obtained from the framework of the LKM process in broiler chickens supply chain are:

a. The process of knowledge creation should ideally unfold organically within conducive and enjoyable environments, devoid of coercion. This approach enhances the cultivation of halal awareness across inter-organizational dynamics. Regarding halal traceability knowledge, the importance lies in persuading business actors of the benefits inherent in adhering to halal assurance system regulations. By complying with the regulations and producing halal products, businesses aim to improve competitiveness and value proposition.

b. Since most of the actors are SMEs, knowledge storage is recommended using media easily accessed in the future, such as written documents in the form of SOPs.
c. For knowledge application, we advise making a checklist in the form of documents required in the halal certification application process.
d. The 7 types of methods for conducting halal education as a form of knowledge sharing include training and workshops, socialization, industry support, lectures at the mosque, school curriculum, volunteers, and organizing halal ambassadors. Meanwhile, knowledge sharing can be conducted through social media, TV, newspapers, leaflets, and podcasts.

5. Conclusions and limitations

In conclusion, the traceability system was reported to be highly beneficial in ensuring the integrity of halal practices. Additionally, broiler chickens represent a food source inherently considered halal but risk losing that status when any stage within the supply chain fails to comply with Islamic law. There were several HCPs for broiler chickens which included three stages, namely the pre-slaughter, slaughter and post-slaughter stages. This study found that most HCPs are in the slaughter stage. Halal certification of a CSH as a representation of the traceability system was only obtained by 12 CSHs in Riau Province. Despite the government's mandate to attain certification by October 17, 2024, compliance has remained a challenge.

This study presents the utilization of the ANP approach to strengthen halal integrity by identifying the important actors within the supply chain tasked with expediting the implementation of a traceability system. This study showed the most influential stakeholders, identified the challenges and barriers, as well as proposed appropriate strategies to address prevailing issues. Additionally, the developed ANP model effectively reported the interrelationships within clusters and the connections among elements. The scope was confined to Riau Province, Indonesia and a one-level ANP approach was used.

This study was centered on the identification of objectives, as well as the criteria for achievement, challenges, barriers, and the formulation of strategies. Future investigations could broaden the scope and adopt a two-level ANP model, incorporating analyses with benefits, opportunities, costs, and risks.

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