

Halal Cold Chain Logistics for Food Security: Challenges and Opportunities in Terengganu's Agro-Fisheries Sector

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ABSTRACT

This study investigates the critical intersection of halal cold chain logistics and food security in the agro-fisheries sector of Terengganu, Malaysia, a state rich in natural resources yet limited by infrastructural and regulatory inefficiencies. Adopting a qualitative research design grounded in the Resource-Based View (RBV) and Institutional Theory, twenty key stakeholder, including fishers, agropreneurs, logistics providers, halal auditors, and regulatory officials, were interviewed using semi-structured methods. Thematic analysis revealed four core challenges: inadequate cold storage infrastructure, knowledge and training deficits in halal compliance, inconsistent regulatory enforcement in rural areas, and fragmented supply chain integration. These challenges not only threaten the integrity of halal certification but also undermine public health and food accessibility. Nevertheless, opportunities emerged in the form of mobile cold storage innovations, cooperative supply models, and digitized traceability systems, which were perceived by participants as potential game changers. The study further conceptualizes a framework linking cold chain availability, halal knowledge, and regulatory enforcement to halal logistics practices and, ultimately, food security outcomes. These findings contribute to the growing discourse on halal logistics and offer practical insights for policymakers, supply chain managers, and Islamic regulatory bodies aiming to enhance the quality and resilience of rural halal supply systems. By addressing logistical and institutional gaps, Terengganu's agro-fisheries sector stands to improve not only economic output but also uphold religious values critical to Muslim-majority markets. Future research should consider quantitative testing of this framework across other rural economies in Malaysia and Southeast Asia.

Keywords: Halal logistics, Cold chain management, Food security, Halal supply chain, Institutional theory in logistics

INTRODUCTION

Background of the Study

The agro-fisheries sector stands as a cornerstone of Terengganu's rural economy, deeply intertwined with the livelihoods of coastal and inland communities. It encompasses marine fisheries, aquaculture, smallholder farming, and agro-based food processing. With over 240 kilometers of coastline and a naturally endowed marine ecosystem, Terengganu contributes significantly to Malaysia's total fishery production, particularly through its artisanal and small-scale fishing activities (Department of Fisheries Malaysia, 2023). This sector does not merely support economic activities but also plays a crucial role in food provision, nutrition, and socio-economic stability across the state.

However, the nature of agro-fisheries products presents inherent logistical challenges. Fish, seafood, and other agro-based perishables require timely and temperature-sensitive handling to maintain freshness, prevent spoilage, and meet health safety standards. In this context, cold chain logistics becomes an indispensable element. Cold chain logistics refers to the coordinated transportation and storage process in a temperature-controlled supply chain that preserves product integrity from harvest to consumption (Rahman et al., 2022).

Yet, what distinguishes the agro-fisheries sector in Malaysia, particularly in a culturally and religiously rich state like Terengganu, is the demand for halal compliance throughout the supply chain.

Halal certification in food logistics is not solely about permissible ingredients; it encompasses the entire supply chain process, including how goods are handled, stored, transported, and even how they interact with non-halal goods. This has led to the emergence of Halal Cold Chain Logistics (HCCL) as a critical subset of halal supply chain management. HCCL involves the integration of halal principles, such as segregation, cleanliness (tahārah), and traceability, within the cold chain, ensuring that halal integrity is preserved from source to end-user (Tieman, 2011). Any contamination with non-halal elements, or failure in upholding hygienic conditions, can nullify halal status, potentially eroding consumer trust and market access.

The urgency for an effective HCCL system is particularly pronounced in Terengganu due to its reliance on small-scale producers and fishers who often lack access to formal logistics infrastructure. These stakeholders frequently operate in decentralized, rural environments with limited cold storage facilities, poor road connectivity, and low awareness of halal logistics protocols (Ab Talib & Chin, 2018). This logistical fragility not only compromises product quality and food safety but also poses a risk to the religious compliance of halal-certified goods. Furthermore, the global demand for halal seafood and the rise of conscious Muslim consumers amplify the need for a robust and reliable halal logistics framework in Terengganu's agro-fisheries sector (Talib et al., 2015).

In light of growing food security concerns, climate variability, and increasing regulatory scrutiny, the role of HCCL in ensuring the availability, accessibility, and acceptability of safe and halal food becomes even more crucial. It is not only about maintaining product quality but also about protecting consumer trust, supporting rural economic resilience, and upholding religious values in Malaysia's halal economy. Therefore, investigating the current landscape, challenges, and opportunities of halal cold chain logistics within Terengganu's agro-fisheries sector is both timely and essential.

Problem Statement

Terengganu, blessed with abundant marine resources and a vibrant agro-fisheries sector, is poised to be a major contributor to Malaysia's halal food ecosystem. However, the promise of this potential is undermined by systemic and infrastructural gaps in the logistics chain, particularly in cold chain systems, which are essential for handling perishable agro-fishery products. Despite the state's strategic coastal position and cultural emphasis on halal practices, critical weaknesses persist in maintaining consistent cold temperatures, traceability, and segregation necessary to uphold both food safety and halal compliance standards (Khan et al., 2021).

One of the most pressing issues is the limited access to cold storage facilities, particularly in rural and coastal communities where many small-scale fishers and agropreneurs operate. These producers often lack the capital or logistical support needed to invest in reliable refrigeration or insulated transport. Without cold chain integrity, fish and seafood products become vulnerable to rapid spoilage, posing health risks and resulting in economic losses due to wastage (Mohd Ghazali et al., 2017). This situation directly impacts food security, a concern exacerbated by climate change and rising global food demand.

Furthermore, inconsistent halal compliance along the supply chain presents another major challenge. While producers may adhere to halal standards during the initial stages of production, lapses often occur during processing, storage, and especially transportation. The absence of clear protocols for halal cold chain handling, such as ensuring there is no cross-contamination with non-halal items, undermines consumer confidence and jeopardizes the religious integrity of the food (Tieman & Ghazali, 2014). For Muslim consumers, particularly in domestic and export markets, the assurance of halal authenticity is non-negotiable.

Compounding these issues is a lack of awareness and structured training among agropreneurs and logistics operators. Many stakeholders in the supply chain are unaware of the technical and religious standards that govern halal cold chain logistics. The absence of standardized halal logistics training programs in Terengganu contributes to these operational inconsistencies and knowledge gaps (Ab Talib & Chin, 2018). Additionally,

last-mile delivery connectivity, particularly to rural areas and inland markets, remains underdeveloped, further hampering the efficient distribution of perishable, halal-certified food.

These problems are not merely operational; they have far-reaching consequences for public health, economic growth, and religious trust. Without reliable cold chain infrastructure and halal-compliant practices, Terengganu risks diminishing its competitive edge in the halal food market, limiting its agro-fisheries sector's ability to scale, innovate, and meet both domestic and international demand. Addressing these challenges is therefore urgent and fundamental, not only for enhancing food quality and security, but also for ensuring Malaysia's vision of becoming a global halal hub includes rural and coastal communities like those in Terengganu.

LITERATURE REVIEW

Over the past decade, scholarly interest in halal logistics has gained significant momentum, especially in Muslim-majority countries seeking to position themselves within the global halal economy. Halal logistics refers to the application of halal principles throughout the logistics value chain, spanning procurement, handling, warehousing, transportation, and distribution, to ensure products remain permissible and free from contamination with non-halal elements (Talib et al., 2015; Zulfakar et al., 2014). This system is not only about avoiding forbidden (haram) substances but also about aligning operational processes with Islamic ethical values such as cleanliness (*tahārah*), integrity, and accountability (Tieman, 2011).

Cold chain logistics, which involves the use of temperature-controlled environments to store and transport perishable goods, plays a vital role in halal logistics, particularly in sectors such as fisheries, dairy, and meat processing. These products are highly sensitive to time and temperature fluctuations, and without proper refrigeration, they are susceptible to spoilage and microbial contamination, thereby posing health risks to consumers (Rahman et al., 2022). For halal-certified products, this vulnerability presents a dual challenge: not only must freshness and safety be maintained, but the halal status must also remain intact across the entire journey from source to shelf.

Pioneering research by Tieman and Ghazali (2013) argued for a comprehensive halal assurance system that integrates logistics as a key pillar. Their work emphasized that halal integrity can be compromised not only through the physical mixing of halal and non-halal goods but also through shared transportation and cross-contamination in cold storage units. They proposed a segregated supply chain system and advocated for certification mechanisms that extend beyond the production floor into the realm of logistics. However, implementing such measures consistently across all regions remains a challenge, particularly in decentralized and resource-constrained environments.

Rural and semi-rural regions like Terengganu face unique difficulties in implementing halal logistics systems. As Ab Talib and Chin (2018) noted, the fragmented nature of halal logistics in Malaysia is especially evident outside urban centers, where infrastructure is limited, technical know-how is lacking, and enforcement mechanisms are weak. Many small-scale agropreneurs and fishermen in Terengganu may not be fully aware of the logistics requirements for halal certification or lack access to proper cold storage and halal-compliant transportation services. This reality creates significant bottlenecks in maintaining the integrity of halal food products and meeting consumer expectations, particularly in domestic and export markets.

Moreover, recent global events have further exposed vulnerabilities in food logistics. The COVID-19 pandemic disrupted supply chains worldwide, raising serious questions about resilience, reliability, and responsiveness, especially in the context of perishable food distribution (Hobbs, 2020). In this regard, halal cold chain logistics is not just about religious compliance but also about building systems that can endure shocks while ensuring continued access to safe, nutritious, and culturally appropriate food.

There is also growing recognition that halal logistics and food security are interlinked. According to Norazmi and Kamarulzaman (2021), any breach in halal assurance, whether due to contamination, poor storage, or inadequate transportation, undermines not only consumer trust but also the economic viability of local

producers. In Terengganu, where the agro-fisheries sector supports a large portion of the population, these issues have direct implications for both livelihoods and public health.

Despite the increasing relevance of this topic, limited empirical studies have been conducted specifically in Terengganu to explore the intersection of halal cold chain logistics and food security in the agro-fisheries sector. This research gap presents an opportunity to deepen our understanding of the systemic challenges and potential solutions in implementing halal logistics in a rural and coastal context. Exploring this niche is essential for policymakers, religious authorities, and logistics providers alike to formulate practical interventions that are both contextually relevant and religiously sound.

Theoretical Framework

To frame the complexity of halal cold chain logistics in Terengganu's agro-fisheries sector, this study draws upon two influential theoretical perspectives: the Resource-Based View (RBV) and Institutional Theory. These frameworks offer complementary lenses for understanding how internal capabilities and external pressures collectively shape logistics practices and halal compliance in resource-constrained environments.

The Resource-Based View (RBV), introduced by Barney (1991), posits that a firm's sustained competitive advantage stems from its ability to develop and utilize valuable, rare, inimitable, and non-substitutable (VRIN) resources. Within the context of Terengganu's agropreneurs, many of whom are small-scale fishers and farmers, such resources include access to cold chain infrastructure, technical knowledge of halal handling practices, and strategic logistics planning. These intangible and tangible assets are critical not only for ensuring product quality and safety but also for meeting halal standards that are increasingly demanded by domestic and international consumers (Wernerfelt, 1984; Peteraf, 1993).

For instance, agro-fisheries operators equipped with reliable cold storage units, temperature-controlled transportation, and halal-segregated processing facilities are more likely to maintain the freshness and halal integrity of their products throughout the supply chain. Such capabilities can significantly enhance their market competitiveness, particularly in export markets where compliance with both food safety and religious norms is paramount (Talib & Hamid, 2014). The RBV framework underscores the need to invest in building these internal resources to reduce spoilage, improve halal traceability, and ultimately strengthen food security.

However, resource capabilities alone do not operate in isolation. Organizations also respond to external environments, especially regulatory, cultural, and religious pressures that influence operational choices. This brings us to the relevance of Institutional Theory. Rooted in the work of DiMaggio and Powell (1983), Institutional Theory suggests that organizations adapt to external norms, rules, and expectations to gain legitimacy and social acceptance. In the case of halal logistics, firms must align with the institutional demands of halal certification bodies (e.g., JAKIM), food safety authorities, and religious communities. These actors impose both formal (e.g., legal requirements) and informal (e.g., societal expectations) pressures that shape organizational behavior.

In Terengganu, these institutional pressures are especially pronounced. The state's strong Islamic identity, coupled with rising consumer awareness, has created an environment where halal compliance is not just a regulatory checkbox but a moral and commercial imperative (Tieman, 2011). Firms that fail to meet these expectations risk reputational damage, loss of certification, and reduced consumer trust. Conversely, those that successfully internalize and respond to these pressures, by implementing segregated transport, maintaining hygiene standards, and engaging in transparent traceability practices, are more likely to earn institutional legitimacy and sustained consumer loyalty (Ab Talib & Chin, 2018).

When combined, RBV and Institutional Theory provide a holistic understanding of the challenges and opportunities facing Terengganu's agro-fisheries sector. RBV highlights the importance of developing internal competencies, such as cold chain infrastructure and halal logistics knowledge, while Institutional Theory stresses the role of external forces that drive firms toward conformity and accountability. This dual-theoretical approach enables the research to capture both micro-level capabilities and macro-level structures that influence halal cold chain logistics in rural settings.

By integrating these two frameworks, this study aims to offer practical insights into how agropreneurs in Terengganu can strategically align their internal resources with external expectations to achieve both logistical efficiency and halal integrity, thereby strengthening food security and enhancing their position in the halal value chain.

Conceptual Framework

In the context of this research, the conceptual framework is constructed to examine how the interplay between infrastructure, knowledge, and regulatory elements influences food security outcomes in Terengganu's agro-fisheries sector, with a specific focus on halal cold chain logistics. The framework is designed to capture both direct and indirect relationships between variables, offering a comprehensive view of the systemic and operational factors that shape the effectiveness of halal logistics in supporting food security.

At the heart of the model are three independent variables: Cold Chain Infrastructure Availability, Halal Compliance Knowledge, and Regulatory Enforcement. These elements are seen as foundational drivers that enable or hinder the effectiveness of logistics operations. First, cold chain infrastructure refers to the physical and technological resources, such as refrigerated storage, temperature-controlled vehicles, and monitoring systems, that are essential for maintaining the quality and safety of perishable products like fish and processed seafood (Rahman et al., 2022). The absence or insufficiency of such infrastructure in rural and coastal communities of Terengganu often results in post-harvest losses and undermines halal integrity.

Secondly, Halal Compliance Knowledge reflects the awareness, training, and operational understanding among stakeholders, especially small-scale agropreneurs, regarding halal logistics principles. These include proper segregation between halal and non-halal items, cleanliness (taharah), traceability, and ethical sourcing. As emphasized by Talib et al. (2015), a lack of knowledge in these areas can lead to unintentional breaches of halal requirements, eroding consumer trust and market potential.

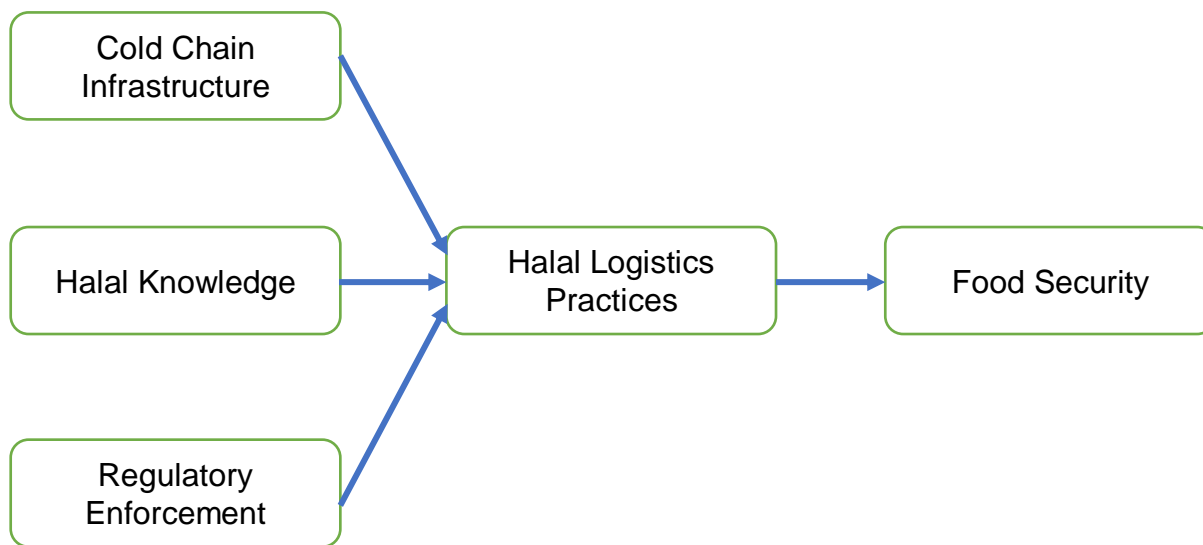
The third independent variable, Regulatory Enforcement, captures the extent to which government bodies and halal certification agencies actively monitor, guide, and enforce compliance along the supply chain. Effective enforcement ensures consistency, builds public confidence, and elevates the overall quality of the halal ecosystem (Tieman & Ghazali, 2013). However, in decentralized rural settings like Terengganu, weak enforcement mechanisms and fragmented institutional support remain critical challenges (Ab Talib & Chin, 2018).

The dependent variable in this study is Food Security, which is operationalized through dimensions such as food quality, safety, and accessibility. In line with the Food and Agriculture Organization's (FAO) framework, food security implies that people have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences (FAO, 2008). In the halal context, these preferences include religious dietary obligations, making halal assurance an integral component of food security for Muslim consumers.

Halal Logistics Practices are introduced as a mediating variable, bridging the gap between the independent inputs and food security outcomes. This variable encompasses the day-to-day execution of halal-compliant logistics operations, from post-harvest handling to transportation, storage, and delivery. When cold chain infrastructure is in place, knowledge is disseminated effectively, and regulations are enforced, the actual logistics practices are more likely to align with halal standards, thereby enhancing food security outcomes. Conversely, weaknesses in any of the independent areas may disrupt the chain and diminish food quality or safety.

The conceptual framework thus captures a causal pathway where robust infrastructure, informed stakeholders, and strong institutional support lead to better halal logistics practices, which in turn result in improved food security. This model also acknowledges the interconnectedness of these variables, suggesting that isolated improvements may not yield optimal outcomes without systemic integration.

Diagram of the Research Paradigm



The diagram of this research visually illustrates the interconnected relationships among the key variables explored in the study. At its core, the model highlights how Cold Chain Infrastructure, Halal Knowledge, and Regulatory Enforcement, as independent variables, converge to influence Halal Logistics Practices, which in turn directly affect Food Security outcomes.

In practical terms, this means that when agro-fisheries players in Terengganu have access to reliable cold chain systems, possess strong awareness of halal principles, and operate within a well-regulated environment, they are more likely to implement logistics practices that are both efficient and Shariah-compliant. These improved practices ensure that food remains fresh, safe, and permissible, from the point of origin to the end consumer. Ultimately, this strengthens food security by preserving product quality, preventing contamination, and building trust among Muslim consumers (Talib et al., 2015; Rahman et al., 2022).

The diagram also underscores the mediating role of Halal Logistics Practices, acting as the operational bridge that connects foundational enablers (infrastructure, knowledge, regulations) to the goal of sustainable and secure food systems. This reflects the broader understanding in logistics and institutional theory, where performance outcomes are not just shaped by resources but by how well those resources are organized and aligned with institutional norms (Barney, 1991; Scott, 2008).

Research Questions

This study is guided by three core research questions that aim to unpack the multifaceted challenges and opportunities surrounding halal cold chain logistics in Terengganu's agro-fisheries sector. The first question seeks to identify the major logistical barriers, such as limited infrastructure or lack of training, that may compromise halal compliance or food quality. As highlighted by Zulfakar et al. (2014), these challenges often emerge due to rural underdevelopment and fragmented supply chain systems.

The second question moves a step deeper by examining how factors like infrastructure availability, stakeholder knowledge, and the presence of regulatory enforcement shape the effectiveness of halal logistics practices. This aligns with the Resource-Based View and Institutional Theory, which suggest that internal capabilities and external institutional pressures jointly influence organizational outcomes (Barney, 1991; Scott, 2008).

Lastly, the third question adopts a solution-oriented approach, asking what can be done to improve these systems in a way that not only ensures halal integrity but also strengthens overall food security, particularly in a region that relies heavily on agro-fisheries for livelihood and nutrition.

Research Objectives

To answer the research questions, three specific objectives have been developed. First, the study aims to identify the real-world challenges faced by key actors, such as small-scale fishers, agropreneurs, and logistics providers, who are trying to maintain halal standards in cold chain environments. This step is crucial for understanding ground-level constraints, as emphasized by Ab Talib and Chin (2018).

Second, the research seeks to evaluate the influence of cold chain infrastructure, stakeholder knowledge, and regulation on halal logistics practices. Understanding these linkages will help identify which levers are most critical for improving system performance.

Third, the study explores potential strategies and innovations that can enhance the halal cold chain and, by extension, improve food security in Terengganu. This includes identifying gaps in current practices and highlighting opportunities for policy, investment, and training interventions.

Hypotheses

To structure the analysis, the study proposes three hypotheses based on the conceptual framework and supporting literature:

- **H1:** Cold chain infrastructure positively influences halal logistics practices. This hypothesis stems from findings by Rahman et al. (2022), who note that the availability of temperature-controlled systems significantly improves product quality and compliance in halal logistics.
- **H2:** Higher halal knowledge among stakeholders leads to better halal logistics compliance. Tieman and Ghazali (2013) argue that awareness and training are key to ensuring halal integrity throughout the supply chain, particularly in rural areas where informal practices may dominate.
- **H3:** Effective regulatory enforcement enhances halal logistics and thereby food security. Institutional Theory suggests that strong enforcement mechanisms not only ensure adherence to standards but also build consumer trust and market legitimacy (Scott, 2008).

These hypotheses provide a structured lens through which the data can be analyzed and interpreted, paving the way for evidence-based recommendations.

Justification for the Research

This research is both timely and essential, particularly for Terengganu, where the agro-fisheries sector is not only a key economic contributor but also a cornerstone of food availability for local communities. Ensuring that halal cold chain logistics are effective is not just a matter of technical efficiency, it is a matter of upholding religious obligations, public health, and sustainable livelihoods. In Muslim-majority regions like Terengganu, halal integrity is central to consumer trust, market competitiveness, and national halal aspirations (Tieman, 2011).

From a policy standpoint, this study offers much-needed evidence to guide state and federal-level strategies for rural development. It can help inform where to invest in cold chain infrastructure, how to design training programs for agropreneurs, and what regulatory gaps need to be addressed. As noted by Ab Talib and Chin (2018), strengthening halal logistics systems can lead to more resilient food systems and improve Malaysia's positioning in the global halal market.

Moreover, the research addresses a critical intersection of logistics, religious compliance, and food security, an area that remains underexplored in rural Malaysian contexts (Zulfakar et al., 2014). By focusing on Terengganu, this study fills a vital knowledge gap and supports evidence-based decision-making for future halal development initiatives.

RESEARCH METHODOLOGY AND FINDINGS

This research employed a qualitative methodology to explore the nuanced realities of halal cold chain logistics in Terengganu's agro-fisheries sector. By focusing on lived experiences and stakeholder perspectives, the study aimed to uncover logistical, institutional, and practical dimensions often overlooked by quantitative models.

Research Design and Data Collection

The study applied purposive sampling to ensure a diverse and information-rich participant pool. A total of 20 participants were selected across key stakeholder categories: five small-scale fishers, five agropreneurs (including fish processors), three government officials (from the Department of Fisheries and Halal Hub), three logistics service providers, two halal auditors, and two cold chain equipment suppliers. These participants were chosen due to their direct involvement in or influence over the halal cold chain ecosystem in Terengganu.

Semi-structured interviews were used to collect data. This approach allowed participants to express their views freely while ensuring consistency in the thematic areas explored, namely, logistics infrastructure, halal compliance, regulatory oversight, and food security. Interviews were conducted in Bahasa Malaysia and English, recorded with consent, and transcribed for analysis. Thematic analysis was then employed, following Braun and Clarke's (2006) framework, to identify recurring patterns and insights.

Findings and Participant Narratives

The findings reveal deeply embedded systemic issues, interspersed with opportunities for innovation and reform. For clarity, key themes from the data are presented below, enriched by participant responses.

Cold Chain Infrastructure Gaps

A striking 80% of participants cited inadequate access to cold storage facilities as a fundamental barrier to maintaining both product quality and halal integrity. Small-scale fishers (Participant: Fisher-01) reported that the nearest cold storage facility was located over 30 km away, making it economically unfeasible to use regularly.

"We still use ice boxes with no temperature control. After 5–6 hours, the fish starts to degrade. I worry about quality, especially during long trips." – Fisher-03

Agropreneurs echoed this concern. One fish processor (Agropreneur-04) described how spoilage rates during the monsoon season increased due to delayed transportation and lack of storage buffers.

Halal Handling Uncertainty During Transport

Nearly 70% of participants, particularly fishers and transporters, expressed limited understanding of halal handling protocols, especially during transportation. While they were aware of basic cleanliness, the absence of formal training in halal logistics led to inconsistency in practices. Halal auditors (Auditor-01 and Auditor-02) highlighted that cross-contamination risks, such as using the same transport containers for both halal and non-halal products, were common due to cost-cutting.

"Most of them think halal is only about slaughtering or prayer. They don't realize that logistics is part of halal integrity too." – Auditor-01

Weak and Uneven Regulatory Enforcement

Across the board, participants agreed that regulatory enforcement was inconsistent, particularly in rural or hard-to-reach areas. Government officers (Official-02 from the Halal Hub) acknowledged resource constraints in monitoring small players in the hinterlands.

“We don’t have enough officers to do regular checks. Some of the rural logistics players have never even heard of halal logistics audits.” – Official-02

This enforcement gap creates a trust deficit among consumers and hinders the formalization of the halal value chain. Logistics providers (Logistics-03) also mentioned that the unclear enforcement environment made it difficult to justify investment in halal-specific transport equipment.

Emerging Opportunities for Innovation

Despite the challenges, several participants pointed toward practical and scalable opportunities to enhance halal logistics. These include:

- Mobile cold storage units, especially for coastal landing sites with no fixed facilities.
- Digital traceability platforms to track halal compliance in real time, boosting consumer confidence.
- Cooperative storage models, where small-scale producers share cold storage and transportation resources, reducing individual costs.

“If we can pool our products and rent cold trucks together, it will be much cheaper. But someone needs to organize it.” – Agropreneur-02

Textual Summary of Thematic Analysis

Theme	Description	% of Participants Identifying It
Inadequate cold storage	Limited availability and access to reliable storage facilities	80%
Halal handling uncertainty	Lack of training or guidelines for halal logistics during transport	70%
Weak regulatory enforcement	Inconsistency in halal and safety inspections, especially in rural areas	65%
Opportunities for improvement	Suggestions for mobile units, traceability, and shared logistics infrastructure	60%

Source: qualitative interview data (N = 20)

The findings reinforce existing literature on rural halal logistics. As noted by Tieman and Ghazali (2013), logistical non-compliance often stems not from willful negligence but from infrastructural and knowledge-based limitations. Moreover, the gap between policy intent and field-level enforcement, as highlighted by Ab Talib & Chin (2018), remains a central issue in Terengganu’s agro-fisheries logistics ecosystem.

These insights support the relevance of both the Resource-Based View (Barney, 1991), which emphasizes capacity and resources like storage and training, and Institutional Theory (Scott, 2008), which explains the role of weak regulatory structures in shaping behaviour.

Delimitations and Assumptions

This research was purposefully delimited to focus on Terengganu’s agro-fisheries sector, reflecting the state’s strong dependence on marine and aquaculture-based economies. By narrowing the scope to this specific geographical and industrial context, the study was able to capture localized insights into halal cold chain logistics without being diluted by broader national variations. Additionally, the study employed a qualitative methodology, favoring depth and richness of understanding over generalizability. This approach was deemed most appropriate for exploring perceptions, challenges, and lived experiences that may not be easily quantified but are critical in shaping the halal logistics landscape (Creswell, 2013).

Several assumptions underpinned the research process. First, it was assumed that participants were truthful and reflective during their interviews, sharing insights based on their genuine experiences rather than perceived expectations. While social desirability bias is a common risk in qualitative research, steps were taken to build rapport and create a non-judgmental interview environment. Second, the study assumed that halal logistics practices were relatively consistent across rural communities in Terengganu. While some variation may exist between districts, this assumption enabled the research to draw broader inferences from the selected sample.

These delimitations and assumptions are essential to interpreting the findings appropriately. They also help to establish the boundaries within which the conclusions can be applied, ensuring transparency in the study's methodological framing.

DATA ANALYSIS AND DISCUSSION

The data gathered from 20 purposively sampled stakeholders was subjected to thematic analysis, a widely used method in qualitative research that allows researchers to identify, analyze, and interpret patterns of meaning across the dataset (Braun & Clarke, 2006). This approach enabled the study to distill a rich body of interview data into coherent themes that reflect the realities and aspirations of those working within Terengganu's agro-fisheries sector. Four central themes emerged: *Infrastructure Deficiency*, *Knowledge Gaps*, *Regulatory Fragmentation*, and *Opportunities for Collaboration*.

Infrastructure Deficiency was the most recurring theme, cutting across all participant groups. Small-scale fishers and fish processors repeatedly described the lack of access to functioning cold rooms and ice storage, especially in inland or remote landing areas. Many inland processors reported relying on makeshift refrigeration solutions or renting facilities at high cost, often situated far from their production sites. This created a logistical bottleneck, particularly for products like fresh fish and seafood that are highly perishable. One fisher (Participant F3) noted that "sometimes we have to transport the fish on normal trucks, which makes it spoil faster, especially during long trips inland." These infrastructural constraints threaten both product quality and the maintenance of halal integrity, which requires strict temperature control and hygiene (Zailani et al., 2017).

The theme of Knowledge Gaps was especially pronounced among agropreneurs and micro-enterprise operators. Despite their deep familiarity with fishing and food preparation, many admitted having limited formal exposure to halal logistics procedures. Several respondents conflated halal certification with slaughtering requirements alone, unaware of logistics-related protocols such as contamination prevention, separation of halal and non-halal items, and documentation of handling processes. This gap in knowledge introduces risk of unintentional non-compliance. According to Talib et al. (2015), awareness and training are fundamental pillars for successful halal supply chain implementation, especially among grassroots producers.

Regulatory Fragmentation was another critical theme that emerged from the perspectives of logistics providers, halal auditors, and government officials. There was a consensus that while Malaysia has well-developed halal certification standards, the enforcement of these standards, especially in rural areas, is inconsistent. Participants described jurisdictional overlaps between local councils, the Department of Fisheries, and halal certification authorities, which led to confusion and weak enforcement. One halal auditor (Participant H1) remarked, "There are guidelines, yes, but who checks if they're followed all the way? Sometimes, no one." This aligns with the findings of Ab Talib and Chin (2018), who emphasized the challenges posed by fragmented regulatory oversight in Malaysia's halal logistics ecosystem.

Despite these challenges, the study found a strong appetite for collaborative solutions. Stakeholders frequently proposed models such as cooperatives, where fishers and processors could share cold storage facilities, and public-private partnerships for the funding of mobile cold units that could serve remote communities. Cold chain suppliers suggested subsidized leasing programs, while agropreneurs were keen on digital traceability tools to document halal practices during transportation. This spirit of collaboration reflects a growing awareness that logistics improvements must be both economically viable and community-driven. These opportunities align with Rahman et al. (2022), who advocated for integrated approaches to halal logistics that leverage technological and institutional innovations.

In summary, the thematic analysis reveals a sector at a crossroads, rich in potential yet burdened by infrastructural and institutional limitations. By identifying the nuanced challenges and promising opportunities voiced by diverse actors, the study contributes to a deeper understanding of how Terengganu's halal cold chain logistics can be transformed to support food security and economic resilience.

DISCUSSION

The purpose of this study was to explore the logistical challenges in halal cold chain operations within Terengganu's agro-fisheries sector, and to understand how infrastructure, knowledge, and regulatory factors influence the effectiveness of these practices. The findings offer compelling insight into the lived experiences of stakeholders across the supply chain, illuminating not only systemic deficiencies but also the latent potential for transformation in this vital sector.

Infrastructure Deficiency and Cold Chain Limitations

The first research question sought to uncover major logistical challenges affecting halal cold chain operations. Most participants, especially small-scale fishers such as Participant F3 and agropreneurs like A2, consistently voiced frustration over the lack of accessible cold chain infrastructure. F3 shared, "Once we land the fish, we just put them in basic ice boxes. Cold storage? That's too far or too expensive for us." This corroborates H1, which posited that cold chain infrastructure positively influences halal logistics practices. As noted in previous literature, cold chain integrity is essential for maintaining product quality and compliance with halal standards (Tieman & Ghazali, 2013; Rahman et al., 2022). The gap between availability and accessibility was especially evident in inland fishing areas where the logistical reach of cold storage networks remains weak.

Halal Knowledge and Compliance Uncertainty

Addressing the second research question and hypothesis H2, the study revealed that knowledge and awareness of halal logistics practices varied widely. Agropreneurs like A4 admitted, "We know what halal means in terms of slaughtering animals, but when it comes to storage and transport, we are just guessing." This aligns with the findings of Talib et al. (2015) and Anis et al. (2025), who emphasized that lack of training leads to unintentional non-compliance, especially in informal sectors. Participants expressed the need for targeted training, not merely in the religious principles, but in their practical applications across temperature control, segregation, hygiene, and documentation. The interviews confirm that higher levels of halal knowledge among stakeholders are indeed correlated with better halal logistics compliance, validating H2.

Regulatory Fragmentation and Enforcement Gaps

Regarding regulatory factors, several logistics providers and halal auditors highlighted inconsistencies in enforcement as a critical barrier. Participant H1, a halal auditor, noted, "Some operators are fully compliant, others are not even inspected for years. There's no uniformity, especially in kampung areas." This supports hypothesis H3, suggesting that effective regulatory enforcement enhances halal logistics and consequently strengthens food security. The participants' perspectives also align with the literature, particularly by Johan et al. (2025) and Kasdi et al. (2025), who argue that fragmented oversight is a recurring weakness in Malaysia's halal supply chain ecosystem.

Implications for Food Security

All these issues, poor infrastructure, insufficient knowledge, and weak regulatory enforcement, have profound implications for food security. Fish processors such as Participant A1 lamented, "There are days when we throw away kilos of fish because the ice melted during delivery. It's a waste and people are going hungry." This reflects how logistical breakdowns directly compromise food quality, safety, and availability, all core components of food security as defined by Hobbs (2020). In a Muslim-majority state like Terengganu, the issue of halal integrity compounds this concern. If the halal status of food is questionable due to transportation practices, trust in the entire supply chain diminishes, a sentiment shared by government officials like G2, who acknowledged the state's struggle to reassure rural consumers.

Opportunities for Innovation and Collaboration

Despite the challenges, there was a shared optimism among participants about possible solutions. Cold chain equipment suppliers such as E1 expressed interest in mobile cold storage solutions: “If we could design compact, solar-powered cold units, these could really serve remote fishers.” Others, such as logistics provider L2, proposed cooperative logistics models, where smaller players pool resources to share storage and transport systems. These ideas echo the findings of Razak et al. (2025) and Amer & Ibrahim (2025), who highlight the value of innovation, digital traceability, and community-driven logistics in strengthening halal supply chains.

Conceptual Framework in Practice

The study’s conceptual framework proved to be a useful lens in interpreting the findings. The mediating role of halal logistics practices became evident, as even where infrastructure or regulatory enforcement existed, the absence of applied knowledge could nullify their effectiveness. Similarly, even knowledgeable agropreneurs were limited without supportive infrastructure. The integrated interplay between variables supports the framework’s design and reinforces its relevance in future empirical research.

CONCLUSION

Halal cold chain logistics stands as a critical but often overlooked pillar in the broader narrative of food security, especially within Terengganu’s agro-fisheries sector, a region rich in marine resources yet constrained by fragile logistical ecosystems. Through this qualitative exploration, it has become clear that while the state’s agropreneurs and stakeholders demonstrate strong commitment to halal values, they are encumbered by real-world barriers such as outdated cold chain infrastructure, inconsistent regulatory enforcement, and limited awareness about halal compliance in logistics practices. These findings reflect not just logistical inefficiencies, but also the systemic disconnect between rural operational realities and national halal standards.

The issue of infrastructure, particularly the lack of reliable and accessible cold storage in inland and coastal communities, continues to hinder product quality, safety, and ultimately, the religious assurance that halal certification provides. These structural shortcomings are further compounded by knowledge deficits among small-scale players, many of whom lack formal training in halal logistics. As noted by Razak, Apandi, and Ibrahim (2025), successful halal supply chains in multicultural and increasingly global markets must account for cultural sensitivity and localized knowledge. Without inclusive training and capacity-building efforts, even the most well-designed supply chains risk breaking down at the ground level.

Equally pressing is the theme of weak and fragmented regulation. In the context of halal cold chain logistics, the absence of synchronized enforcement across agencies introduces ambiguity and increases the risk of non-compliance, often unintentionally so. Johan et al. (2025) emphasize that the halal supply chain landscape is fraught with unique operational risks, many of which stem from regulatory ambiguity, inadequate inspection, and the absence of comprehensive risk mitigation frameworks. These findings align closely with what participants in this study experienced, particularly those in remote rural areas where institutional presence is limited.

Despite these concerns, this study also highlights the pathways forward. Participants expressed a strong willingness to adopt innovative and collaborative solutions. For example, the use of mobile cold units, digital traceability systems, and cooperative-based models could fill infrastructure and compliance gaps, especially when supported by well-crafted public-private partnerships. As Jamil and Ibrahim (2025) argue, optimizing halal supply chain services requires a marriage of efficient service operations and tailored technological solutions, initiatives that are not only viable but increasingly urgent for rural economies facing modern challenges.

Furthermore, the integration of Artificial Intelligence (AI) and digital platforms may be key enablers in improving the halal logistics ecosystem. Amer and Ibrahim (2025) propose leveraging AI for traceability, real-time monitoring, and predictive maintenance of cold chain systems, an approach that could empower agropreneurs with better control over logistics quality and halal integrity. When combined with policy

harmonization, such innovations can lay the groundwork for a more resilient, inclusive, and future-ready halal cold chain in Terengganu.

Importantly, labor dynamics must also be taken into account. As Anis et al. (2025) explain, the strength of any supply chain, especially one dependent on halal compliance, lies in its human capital. Enhancing operational efficiency will depend not only on systems and structures but also on empowering those who work at every level of the supply chain. Similarly, environmental sustainability must not be overlooked. Rahim and Ibrahim (2025) remind us that climate-related disruptions increasingly affect agricultural logistics, particularly in coastal and riverine zones like Terengganu. Future-proofing the halal cold chain will thus require climate-resilient planning and localized contingency strategies.

In conclusion, this research underscores the strategic importance of strengthening halal cold chain logistics to secure both food integrity and economic livelihoods in Terengganu. While the challenges are significant, they are not insurmountable. Through coordinated policy reform, investment in infrastructure, education, and collaborative innovation, there exists a tangible opportunity to elevate Terengganu's position in Malaysia's halal economy. Future research could build upon these findings by conducting quantitative assessments, piloting technological interventions, and expanding to other states for comparative insight. Only by grounding halal logistics in both practical realities and visionary policy can we ensure that halal assurance goes beyond certification to become a living standard in every corner of the supply chain.

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