

## Planning of Halal Compliance Critical Control Points and IoT Integration in Halal Chicken Meat Supply Chain Traceability System

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**Abstract:** Halal chicken meat supply chain (HCMSC) is a Syariah-compliant supply chain which embeds multiple critical control points meant for preserving Halal integrity and ensuring food safety and quality of chicken meat. According to MHMS 2020, halal critical point is at which determination of halal control which needs to be identified, implementing control and contamination can be prevented or eliminated to ensure halal compliance along the supply chain. Halal Traceability System (HTS) is essential in HCMSC to ensure track and trace ability of product's information at certain identified critical control points from its origin until it reaches consumers. These critical control points are the key components in Halal Assurance System (HAS) to apply for Halal certification. The objective of this study is to identify Halal traceability critical control points (HTCCPs) in HCMSC in Malaysian scenario and explores the potential planning of Internet of Things (IoT) in food traceability system. This is accomplished by conducting a structured review of past studies concerning halal traceability and the IoT as the traceability tool. The study identifies seven HTCCPs across pre-slaughtering, slaughtering, post-slaughtering, and end consumer phases and IoT integration as the support platform in HTS-HCMSC framework.

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## 1. Introduction

Halal is not a new concept, particularly in Islamic dietary. It is obligatory to Muslims to consume Halalan-toyyiban food as mentioned in the Qur'an: "O ye people! Eat of what is on earth, lawful and good; and do not follow the footsteps of the evil one, for he is to you an

avowed enemy.” (Al-Baqarah, 2:168). Halalan-toyyiban food refers to food which are Halal or ‘permissible’ according to Syariah (sometimes spelled Shariah) and toyyiban. According to Alzeer *et al.* (2017), food which are “toyyiban” or “good” are food that are safe, pure, wholesome, and nutritious. For Muslims, consuming Halal and toyyiban food signifies total submission to Allah, to stay healthy, pure, and righteous while for the non-Muslims, Halal food is preferred because of their quality and wholesomeness.

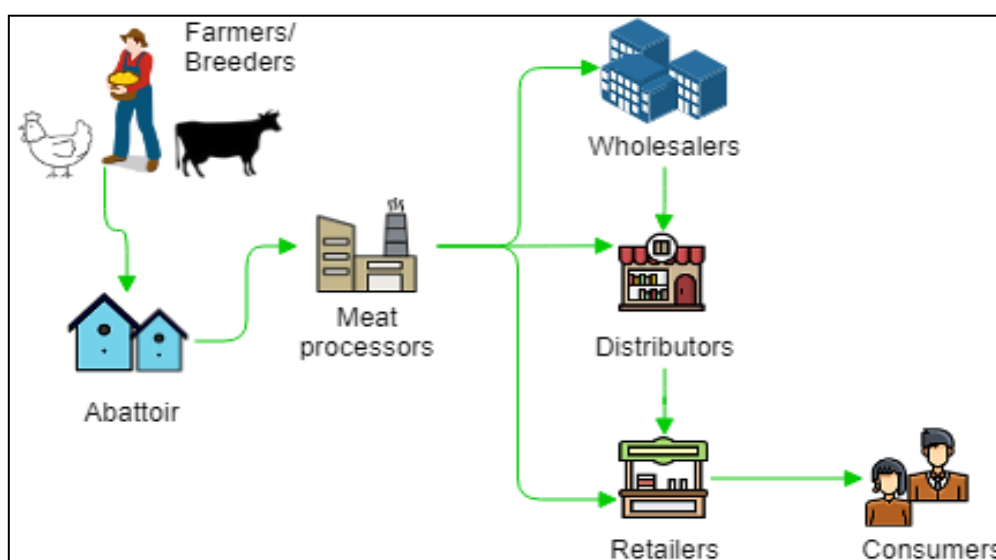
Halal supply chain (HSC) refers to the supply chain of products and services where Halal integrity throughout the network is ensured. Meanwhile, Halal food supply chain (HFSC) describes the food supply chain where Halal integrity is preserved from the point where they are originally produced to the point they are consumed. Soon *et al.* (2017) describes that Halal integrity from farm to fork in HFSC must be preserved in six major phases: agricultural, slaughtering, processing, storage, logistics and audit phases. This is to guarantee Halal authenticity, or “Halalness”, which includes only Halal species are farmed, no cross-contamination with haram products, animals not consuming haram feed, proper slaughtering, food being sourced lawfully, and Halal certification by Islamic authority. Based on Shuib *et al.* (2021), for HFSC, traceability and trackability of Halal integrity and Halalan-toyyiban must include the aspects of food hygiene and safety, the contents/ingredients, the equipment as well as utensils being used, packaging approach and details, storage methods, processing methods, handlings during transportation, and the way in which the waste is being managed.

Respectively, Halal meat supply chain (HMSC) expects that Syariah compliance (Halal) and toyyiban must be adhered in pre-slaughtering, slaughtering, post-slaughtering stages of animals and all methods, processes, and activities in breeding, rearing, processing packaging, and transporting the animals or the products (Ibrahim *et al.*, 2023; Rejeb, 2018; Yang *et al.*, 2016). Poultry is among the most common sources of meat. In 2020, poultry meat has been one of the most consumed animal proteins worldwide (Shahbandeh, 2021). In Asia Pacific itself, demand for poultry shows significant increase due to rapid urbanization, population growth and advance breeding technology (Mordorintelligence, 2021). The poultry consumption per capita (PCC) of Malaysian in 2020 was estimated as 49.3 kilograms per year (Statista, 2021). As defined in Malaysian Protocol for the Halal Meat and Poultry Productions (JAKIM, 2013), poultry consists of domestic fowls, together with ducks, chickens as well as geese, turkeys, in addition of guinea fowls as well as pigeons. However, only chickens, ducks, turkeys, ostriches and quails are allowed to be slaughtered and processed. In Malaysia, chicken is among the most highly consumed sources of protein besides chicken/duck eggs, and fish and seafoods (Department of Statistics Malaysia, 2021). Approximately 66% percent of Malaysians are Muslims (Statista, 2021), thus Halal poultry meat need to be supplied for the Muslims’ consumption.

Halal chicken meat supply chain (HCMSC) represents a Syariah compliant supply chain in which multiple critical control points are embedded as means for preserving Halal integrity and ensuring food safety and quality of chicken meat, particularly the broiler meat, and

chicken-based products. Halal integrity in HFSC in general, and HMSC, and HCMSC, in particular, can only be guaranteed if all Halalan-toyyiban standards are complied, followed, and implemented at all the stages of the supply chain. Figure 1 presents the stakeholders involved in the upstream, midstream and downstream activities along the halal meat supply chain. The important stages (phases) of HCMSC are as follows: pre-slaughtering stage (hatchery and poultry feed supply; broiler house), slaughtering (slaughterhouse or abattoir) and the post-slaughtering stages (processing, packaging and storage, distributors/wholesalers or food industries; and retail outlets and food services) (Shuib *et al.*, 2021). Halal certified chicken assures Halal integrity in HCMSC from farm to fork. In addition, based on Hafez *et al.* (2015), Halal slaughtering method results in better meat quality and better shelf life.

**Figure 1.** Typical Halal Meat Supply Chain (Rejeb,2018)



Hazard Analysis Critical Control Point (HACCP) was originally introduced in the 1960s as a quality assurance system for enhancing food safety and quality (Pal *et al.*, 2016). HACCP enables the identification, assessment, and control of hazards to guarantee food is safe for human consumption and it is applicable to food businesses of any sector that deals with food preparation (SIRIM, 2021). Food safety hazards can be divided into four main categories, which are biological (contamination of food by microorganisms, i.e., bacteria, viruses, and parasites), chemical (presence of harmful substances that occur naturally or intentionally, or unintentionally added chemicals, like pesticides), physical (foreign objects found in food products) and allergenic (allergies to specific substances in food) (SIRIM QAS, 2021). Halal compliance control points (HCCP), also referred to as Halal critical control points (HCCP), are the basic Halal requirements based on Qur'an and Syariah used along with HACCP requirements to certify that the products are Halal compliant according to Halal certification and compliance system (Jalil & Qamar, 2019; Ur-Raheem & Demirci, 2018). Combining HACCP principles with Halal requirements in HCCPs provides the foundation for development of HAS (Demirci *et al.*, 2016; Kohilavani *et al.*, 2013; Lau *et al.*, 2016).

Malaysia Halal Management System (MHMS), or MHMS 2020, replaces the Guideline for Halal Assurance Management System of Malaysia Halal Certification (Halal Malaysia Official Portal, 2021). MHMS 2020 is comprised of two Halal management systems, namely Internal Halal Control System for small and micro industry and Halal Assurance System (HAS) for large and simple enterprises. MHMS2020 is to be used as a reference related to the requirements of internal Halal control for domestic and international Malaysian Halal certification. In MHMS 2020, Halal Control Point (HCP) is defined as point for halal control that needs to be identified and control to be implemented so that Halal contamination can be handled, avoided, or eliminated assuring compliance along the supply chain. According to Ramli *et al.* (2020), HCPs are the key components of the HAS. HAS is implemented as the pre-requisite program to apply for Halal certification. As emphasized in (Jais, 2016), HCP is the important stage in the development of HAS in which it is a process in the process flow where measures can be taken to avoid Syariah incompliance such that HAS is established around the HCPs to achieve Halal integrity of production. Ramli *et al.* (2019) identified five HCPs in the broiler chickens farming. HCPs and critical control points (CCPs) emphasize similar aspects, in this case, to indicate the points at which food safety hazards can be eliminated, prevented, and reduced to safety level. As described by Razaly (2018), the HCPs focus on any threatening elements that may affect the products' Halal status whereas CCPs scrutinize for any threat that can harm the safety status of the product. Combined approaches involving both HCPs and CCPs will be advantageous towards preserving Halal integrity (free from any contamination of haram substances) and assuring food safety (Ramli *et al.*, 2020).

Halal Traceability Systems (HTS) are essential for HFSC. In the context of HFSC, HTS refers to a system that can gather and provide information that could certify that the product is Halal. Traceability is the ability to track and trace from certain points of the downstream and upstream parts of the supply chain all information concerning the product that includes product's details and history as well as whereabouts from its origin until it reaches the consumers, i.e., "from farm to fork". Usually, food traceability systems also include process traceability and customer traceability. Food traceability systems offer a mechanism for greater traceability, transparency, and integrity of product; enhanced food safety and quality; improved processes, management, and customer service; facilitate fast action and mitigation of issues and risks; and increases a brand's trustworthiness and reputation (Alfian *et al.* 2020, Hong *et al.*, 2018)). IoT and blockchain technologies have been identified as key technologies in facilitating HFSC traceability, transparency, and sustainability (Rejeb *et al.*, 2021; Tan *et al.*, 2020; Tsang *et al.*, 2019; Wu *et al.*, 2022). Among the importance of HTS in HCMSC are transparency, traceability, quality assurance, food safety and adherence to standards. This is followed by the availability aspect as well as data accuracy, well-managed disaster food disaster management, informed choices, especially for customers that can boost products standing, and, most importantly, a trusted Halal certification (Shuib *et al.*, 2021). Subsequently, the identification of HACCPs, HCCPs, HCPs, and CCPs is among the fundamental elements of HAS that needs to be considered when developing the HTS for the

HCMSC. The concept of Halal Traceability Critical Control Point (HTCCP) for the HCMSC, which will be described later, stems from the control points circumscribed in HAS.

This paper focuses mainly on discussing the Halal traceability critical control points (HTCCPs) in HCMSC. The remaining of this paper is organized as the following: Literature Review, Methodology, Results and Discussion, and Conclusion. The aim of the study is to identify HTCCPs in HCMSC during pre-slaughtering phase, slaughtering phase, post-slaughtering phase and the end consumers' phase.

## 2. Materials and Methods

In order to propose IoT implementation, the role and suitability of IoT at different stages are analysed. The research method is divided into two phases (A and B). In Phase A, a systematic literature review was done, particularly in HCMSC, to discover the points to be found as Halal critical points along the supply chain phases. In Phase B, a review from past studies in IoT technology is also conducted to explore the roles and functions of Internet of Thing (IoT) in food traceability and transparency at identified HTCCPs of the HCMSC.

In Phase A, three plus one phases, namely the pre-slaughtering phase, slaughtering phase, post-slaughtering phase, and the end consumers' phase, have been listed in HCMSC based on the structured review of previous studies (Shariff and Mohzal, 2019; Shuib *et al.*, 2021).

In Phase B, seven stages are determined, namely [1] pre-slaughtering (breeders & hatcheries), [2] pre-slaughtering (farm), [3] slaughtering (slaughterhouse), [4] post-slaughtering (processing, packaging, and storage), [5] post-slaughtering (distributors and food industry), [6] post-slaughtering (retail and food services), and [7] product traceability. These stages are then identified as the Halal traceability critical control points (HTCCPs) of the HCMSC. HTCCPs are the points for Halal data flow checklists, and Halal data integrity check and verification. IoT-based environment is implemented as the traceability and transparency approach. The device is set in three plus one phases to capture essential data from the beginning of supply chain till the end. Later, during transportation and logistics activities, a sensor acts as a tool for temperature and humidity measurement of the meat in the storage. The whole network is connected by a wireless connectivity and integrated as one IoT environment where data capture and exchange happen, as shown in Figure 2. Finally, information on the chicken or chicken-finished products, either on the product's origin, Halal and food quality and safety assurance, and information tracing/tracking in case of product recall, are all transparent, traceable, and accessible to the consumers.

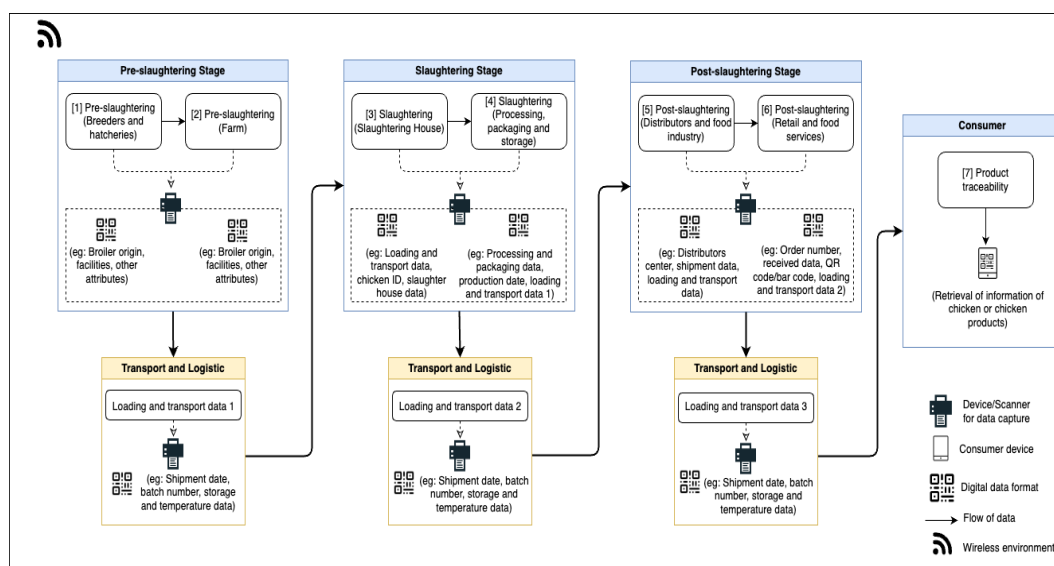


Figure 2. IoT Environment Planning of HCMSC.

### 3. Results and Discussions

The analysis started with discussing the seven HTCCPs identified across the pre-slaughtering, slaughtering, post slaughtering, and the consumers phases. Each of the HTCCPs has its corresponding set of data to be recorded, updated, and verified. In pre-slaughtering phase, HTCCP 1 and HTCCP 2 captured, controlled and monitored data concerning hatcheries and poultry feed suppliers, and broiler houses, respectively. In the next stage, in the slaughtering phase, only one HTCCP 3 is identified in which it deals with data related to the slaughterhouse, especially concerning Syariah requirements on slaughtering procedure. Three HTCCP are categorized in the post slaughtering procedure. HTCCP 4 keeps tab of data on processing, packaging, and storage. In HTCCP 5, all data associated to distributors and food industry are scrutinized, whereas in HTCCP 6, data integrity check were done on retailers and food services, such as the product barcodes, display shelves data and customer’s proven receipt. Finally, HTCCP 7 is identified for the plus one section, consumer’s phase, ensures accurate database for customers’ access to information. Logistic and transportation data are embedded at every phase, which first set of the data are embedded in HTCCP 3 while the remaining data on logistic and transportation are tagged to HTCCP 5. The details of each data collected at each phase, its HTCCP and the traceable data by HCMSC phases are shown in Table 1.

Based on the results summarized in Table 1, a proper planning of data keep, and data retrieval can be done. For example, at the pre-slaughtering phase, the certificate of origin, facilities, and attributes need to be captured by the system as well as be used as the tracking element. This section can be divided up into subheadings. This will provide a detailed and concise description of the experimental observations, their interpretation and the experimental conclusions which can be drawn.

**Table 1.** Data Retrieved in each of the HTCCP Phases

Phase	HTCCP	Needed Data
<b>Pre-slaughtering</b>	• HTCCP 1: Breeders and Hatcheries	<ul style="list-style-type: none"> <li>• Certificates (origin, facilities and attributes)</li> <li>• Process and pictures (Shuib <i>et al.</i>, 2021)</li> <li>• Certificates (origin, facilities and attributes)</li> </ul>
<b>Pre-slaughtering</b>	• HTCCP 2: Farm	<ul style="list-style-type: none"> <li>• Process and picture (Shuib <i>et al.</i>, 2021)</li> </ul>
<b>Slaughtering</b>	• HTCCP 3: Slaughtering House	<ul style="list-style-type: none"> <li>• Loading &amp; Transport 1 data_(Shuib <i>et al.</i>, 2021)</li> <li>• Order number</li> <li>• Shipment date</li> <li>• Chicken ID</li> <li>• Processing &amp; Packaging data</li> <li>• Barcodes</li> </ul>
<b>Post-slaughtering</b>	• HTCCP 4: Processing, Packaging and Storage	<ul style="list-style-type: none"> <li>• Item number</li> <li>• Production date</li> <li>• Expiry/Best before date</li> <li>• Storage and temperature data</li> <li>• Transport temperature data</li> <li>• (Shuib <i>et al.</i>, 2021)</li> <li>• Loading &amp; Transport 2 &amp; Transport 3 data_(Shuib <i>et al.</i>, 2021)</li> </ul>
<b>Post-slaughtering</b>	• HTCCP 5: Distributors and Food Industry	<ul style="list-style-type: none"> <li>• Distribution centre</li> <li>• Packaging barcodes</li> <li>• Shipment data</li> <li>• Order number</li> <li>• Transport temperature data</li> <li>• Order number</li> <li>• Received date</li> </ul>
<b>Post-slaughtering</b>	• HTCCP 6: Retail and Food Services	<ul style="list-style-type: none"> <li>• Packaging barcodes</li> <li>• Storage &amp; temperature data</li> <li>• Display shelves data</li> <li>• Invoice data</li> <li>• Customer's receipt data</li> <li>• (Shuib <i>et al.</i>, 2021)</li> <li>• Halal certification of product</li> </ul>
<b>Consumer</b>	• HTCCP 7: Product Traceability	<ul style="list-style-type: none"> <li>• Supply chain actors</li> <li>• Product origin and history</li> <li>• Product ingredients details</li> <li>• Production process</li> <li>• (Shuib <i>et al.</i>, 2021)</li> </ul>

Integrating IoT into the halal meat or chicken supply chain involves several practical considerations and challenges that entrepreneurs should address, depending on the size of the business (medium/large or small industries). The halal meat or chicken supplier can either be medium/ large or small industries with different considerations when it comes to decision on integrating the IoT into their business. Among which are on the infrastructure readiness as there is a need to invest in high-quality IoT devices like RFID tags, sensors, and cloud computing systems, in order to ensure stable and scalable internet connectivity, especially

for real-time monitoring across multiple locations. As for small Industries, the focus on affordable IoT solutions such as basic QR code systems or low-cost sensors should be considered in order to address the potential lack of consistent internet access, especially in rural areas. At the same time, both medium/large and small industries need to ensure IoT systems are programmed to meet regulatory and certification body requirements, such as JAKIM in Malaysia at every stage.

For medium/large Industries, integrating IOT into the halal meat or chicken supply chain requires Return of Investment (ROI) and Cost analysis. There is a need to allocate budgets for IoT integration, ongoing maintenance, and staff training as well as to justify ROI by leveraging IoT data to optimize processes, reduce waste, and improve traceability. Similarly, the small industries need to seek cost-effective IoT solutions or partnerships to minimize initial investment and explore subsidies or government grants tailored for halal industry advancements.

More challenges will be in handling customer expectations as the integration requires transparency from the supplier. Hence, medium/large Industries need to consider to provide real-time traceability and tracking information to customers via apps or portals and highlight IoT-enabled halal certification processes as part of branding. The small industries might want to explore the use of simple digital tools to share key traceability data, such as QR codes on packaging and build trust by showcasing IoT's role in ensuring halal compliance. By integrating IOT into the halal meat or chicken supply chain, both medium/large and small Industries can ensure to environmentally sustainable environment by using IoT to monitor energy and resource usage for more sustainable operations and through predictive maintenance of storage facilities, the food waste can also be minimised.

Entrepreneurs must balance innovation with practicality when integrating IoT into the halal meat supply chain. Understanding the scale of operations and prioritizing traceability, compliance, and customer trust are key to successful IoT adoption for both medium/large and small businesses.

#### **4. Conclusions**

HTS of HCMSC (HTS-HCMSC) enables traceability at multiple critical control points as means for ensuring Halal authenticity as well as food safety and quality of chicken (broiler) meat and chicken meat-based products. As described in this paper, these critical control points include HACCPs, HCCPs, HCPs, CCPs, and HTCCPs. These critical control points have different roles and functions and are usually considered as the essential components of the Halal Assurance System (HAS). In this paper, based on our study, HTCCPs, in particular, are defined as the identified points for Halal data flow checklists, and Halal data integrity check and verification in HTS-HCMSC that enables for proper planning of the IoT system flow. Identification of HTCCPs contributes towards the functionality of HTS in HCMSC to certify Halalness of product by offering comprehensive, accurate and integrated system to ensure track and trace ability of product's information from its origin to consumers as final destination, in which the significance of IoT is highlighted and very much needed for transparency. The reviews presented in this paper highlight the role of IoT throughout the



HCMSC. In this study, IoT enables a wireless integrated environment consisting of integrated sensors and connected devices for seamless communication exchange, mostly during logistic and transportation phases. Despite working as a system integrator, IoT supports as an enabler for data collection, capturing, and tracing of HTCCPs among phases. Finally, as one of the advanced food traceability technologies, IoT has enhanced the traceability and transparency of the HTCCPs in HCMSC of this study.

**Supplementary Files:** The list of abbreviation is listed at the end of this article.

**Author Contributions:** “Conceptualization and methodology, I.I., A.S. and F.H.Y.;,Z.; formal analysis, investigation & writing the original draft, I.I. & A.S. writing—original draft preparation, I.I.; supervision, A.S. & F.H.Y.; writing—review and editing, S.R.S.

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**LIST OF ABBREVIATIONS**

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<b>ABBREVIATIONS</b>	
<b>HCMSC</b>	Halal Chicken Meat Supply Chain
<b>HTS</b>	Halal Traceability System
<b>HAS</b>	Halal Assurance System
<b>HTCCPs</b>	Halal Traceability Critical Control Points
<b>IoT</b>	Internet of Things
<b>HAACP</b>	Halal Analysis Critical Control Point
<b>HCCP</b>	Halal Critical Control Point
<b>MHMS</b>	Malaysia Halal Management System
<b>HCP</b>	Halal Control Point
<b>CCPs</b>	Critical Control Points
<b>HFSC</b>	Halal Food Supply Chain

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