Monitoring of beef cold chain to ensure quality, safety, and halal using RFID: A review

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Abstract. The traceability application by the industry to ensure products along the supply chain include quality, safe and halal. Traceability is an essential part of the cold chain system for meat and meat products. The cold chain of beef, including a slaughterhouse, distribution, and retail, needs to be monitored. The decline in the beef quality is marked by sensory changes such as color, unpleasant odor, and mucus formation triggered by bacterial growth. Beef quality is easily damaged during distribution due to the complexity and length of the cold chain. Consumers also pay attention to the halalness of beef in the supply chain. The implementation of Radio Frequency Identification (RFID) can monitor changes in quality and halalness of beef when distribution utilizes various sensor and product information tags. RFID requires a transponder to store and retrieve data remotely, an antenna for transponders, and a reader. This article reviews the RFID traceability system, the cold supply chain for beef, and RFID development to maintain beef quality, safety, and halalness. RFID technology helps producers and consumers to get quality, safe, and halal beef information in real-time.

1. Introduction

Animal products are the main source of protein for humans. This product is in the form of meat and processed meat. Meat consumed by beef is second in Indonesia, in 2020 it is estimated at 2,680 kg/capita/year [1], while the estimated beef production in 2020 is 515 thousand tons [2]. Beef products include highly perishable ingredients that have the potential to endanger consumer health if not handled properly. It is crucial to monitor the quality and safety of beef along the cold chain. The cold chain serves to keep the meat fresh during distribution. Cold chain development encourages beef circulation, reduces resource loss, and increases social resource benefits [3].

Problems in the beef cold chain are refrigeration before shipping, product transfer between supply chain actors, long lead times, and temperature fluctuations during distribution. Temperature fluctuations result in variations in beef quality during shipping. The quality of beef decreases, marked by the emergence of bacteria that cause spoilage. Harmful bacteria cause beef to be non-halal for consumption [4]. A cold chain traceability system is needed to reduce the decline in food quality and safety in distribution and build a good food logistics system. Traceability is the ability to follow and study in
detail or every step of the activity or process related to the supply chain. Traceability information is used in the upstream supply chain, for example, product ordering and downstream, for example, the distribution process [5]. Data in the traceability system includes a cattle passport database and electronic data from markets, slaughterhouses, third-party agents, and other organizations involved in beef distribution. Currently, RFID is used as a technology to monitor beef quality during distribution from farm to fork.

RFID is an identification tool that uses a wireless microchip to create tags and utilizes radio waves, so it doesn't need to contact the reader. The phase of reading the data on the tag is high-speed and automatic. To gather information from RFID tags, a reader connected to the internet is necessary. This reader can be installed in cross-docking depots, and thus temperature logs can calculate the remaining shelf life of the product [6]. RFID technology provides benefits to easily identify product information applicatively. Information about food safety and food security guarantee systems is needed and easily accessed with RFID tracking technology [7]. This review discusses the use of an RFID traceability system in the cold supply chain for beef to help decision-makers develop this technology for producers and consumers to monitor meat quality in real-time.

2. Methods
This paper uses a systematic review approach as the primary method of surveying and analyzing the literature. A systematic review has criteria in which article review is carried out in a structured and planned manner [8]. Systematic reviews have been chosen to reduce bias by identifying, appraising, and synthesizing relevant studies on a particular topic [9]. Systematic reviews also increase reviewing and making summaries of research evidence. Literature studies and surveys on quantitative and qualitative empirical studies have been published, such as journals, books, encyclopedias, and internet resources. Journals, books, and encyclopedias can be accessed at the publishers Elsevier, Emerald Insight, Hindawi, Springer, Google Scholar, and Taylor & Francis Group. The search used the keywords “traceability system”, “RFID” “meat quality”, “meat safety”, “halal meat”, “cold chain”, and “meat cold chain.”. The publications were analyzed in the period 2002-2020.

3. Halal beef cold chain
Halal is an essential factor for Muslim consumers to choose food. Many Muslim consumers want halal beef. Beef halal assurance is not only the final product but every stage of the cold chain. The cold chain is part of the supply chain to maintain the quality during the process to consumers and is designed appropriately to minimize damage [10]. The halal food supply chain level is divided into four stages: farming, slaughtering, transportation, handling, storage, distribution, and consumption (Figure 1) [11].

![Figure 1. Halal food supply chain](image)

The farming stage ensures that all meat from animals is halal. The slaughtering stage ensures that all halal animals are slaughtered in the name of Allah and using very sharp slaughtering tools. Stages of transportation, handling, storage, and distribution with tools free from contamination by dirt and non-halal materials. The consumption stage ensures that halal food is labeled so that consumers can ensure that the food purchased is halal.

3.1 Beef quality & safety
Meat quality is a broad term encompassing a variety of characteristics. Beef quality is identified when consumers buy, eat, and select raw and processed meat. Parameters that determine meat quality include
sensory perception. Appearance, color, taste, texture, juiciness, and smell are sensory perceptions of consumers. In addition to sensory, meat and carcass quality parameters are shown in Figure 2 [12,13].

![Figure 2. Meat and carcass quality parameter [13].](image)

Color is an essential parameter of food product quality and is used as one of the parameters for the physical and chemical quality of the product [14]. The color of beef that consumers want is cherry red. The increase in the reddish color of beef is due to higher myoglobin. Myoglobin is the main pigment of meat, accounting for 50-80% of the total pigment. Hemoglobin, the primary color pigment in blood. Discolored flesh is considered an indication of spoilage and is unhealthy. Color defects lead to rejection of meat by consumers. Color is the most crucial feature controlled in the cold chain of fresh meat [15,16].

Juiciness is also an essential factor in meat quality. The determinant of the juiciness of the meat is the temperature at the endpoint. The higher the endpoint temperature, the lower the juiciness of the meat [17]. Juiciness there are two stages of assessment. First, the juiciness of meat is obtained from its storage capacity. Second, the juice flows from the fat, giving consumers another dimension or impression of moisture [18].

Odor-related qualities. Fresh and good-quality meat has a normal smell. Rancid or strange-smelling beef should be avoided. Tenderness is associated with several factors, such as the animal's age, sex, or muscle location. One crucial way of tenderizing meat is by aging. During aging, cytoskeletal protein degradation occurs. Carcasses were stored at refrigeration temperature for a long time post-slaughter and pre-cooling. Tenderness is a significant contributor to meat satisfaction and consumer acceptance. Therefore, tenderness is considered a vital trait influencing repurchase decisions [19,20].

Meat is a perishable food product unless processed, packaged, distributed, and stored properly. Overgrowth of pathogenic bacteria due to improper handling can be harmful to consumers. These bacteria trigger the spoilage of meat. Meat spoilage includes changes in the substrate (e.g., low molecular compounds) mostly triggered by spoilage bacteria [21]. Pseudomonas, Lactobacillus, and
Enterococcus, produce mucus in meat. Enterococcus has a greenish color due to hydrogen peroxide similar to a greenish color due to hydrogen sulfide caused by Clostridium spp. Bacterial growth in meat is influenced by temperature, pH, water activity, nutrient availability, storage atmosphere and competition with other organisms, and small changes in these factors greatly affect spoilage [22].

3.2 Halal beef
In addition to focusing on the sensory quality of meat, producers must ensure that their meat products are halal. Halal meat production requires animal welfare practices starting from animal husbandry. Animals do not treat properly result in fatigue, bruising, and injuries resulting in poor meat quality. Poor animal care on farms increases the potential for animal disease. According to sharia law, animals to be slaughtered must be given good, clean, halal, and nutritious food in order to produce halal meat. The halal system also pays attention to animal welfare during transportation. Good transportation avoids over-trucking, reduces animal stress before slaughter affects meat quality [23,24]. Distribution arrangements prevent the emergence of harmful bacteria that cause rotting and non-halal meat.

Proper pre and post-slaughter practices to obtain halal meat must be carried out by producers. Pre-slaughtering practices include the use of bridles to restrain livestock which facilitates the slaughtering process and safeguards the animal's welfare to be slaughtered. Safe restraints protect animals from distress, pain, bruising, and injury [25]. Cutting of the main blood vessels with a sharp, one-piece knife allows for rapid blood loss, thereby reducing spoilage, prolonging shelf life, and producing safe and high-quality meat [26,27]. Post-slaughter is one of the critical stages in determining the quality of meat. At this stage, the shelf life and hygienic maintenance of meat products are very important. In the halal system, the *toyyib* aspects, including nutrition, quality, hygiene, and product safety, require meat to be free from microbiological, physical, and chemical hazards. After the slaughtering, meat is handled and processed hygienically to avoid cross-contamination during storage. Storage temperature during transportation needs to be monitored to prevent microbial growth. Meat quality can be maintained with a longer shelf life. From processing to transport, the risk of harm at every stage must be eliminated to maintain the *toyyib* aspect of meat [23, 28].

3.3 Beef cold chain
Food cold chains utilize freezing, refrigeration, supply of raw materials, product processing, storage, transportation, distribution, and retail technology to consumers. Each stage of the product needs low temperatures to ensure food quality and safety, minimize losses, prevent contamination of the supply chain system [29]. The vulnerability of the meat cold chain becomes very important in the meat trade where the distribution chain is very complex and long, including slaughterhouse-transportation-retail-consumer. Meat is sent from one area to another. Schematically, the cold chain of meat is shown in Figure 3. Cold chain management is very important and is a challenge to maintain the safety and freshness of meat reaching the final consumer [30].

![Figure 3. Schematic diagram of meat cold chain](image-url)
Before transportation, meat should be stored below 4˚C. Meat and meat products must be packaged and inspected prior to distribution. Meat is packed into packages, boxes, or crates when transported, and contact with humans is limited. During distribution, the temperature must be kept within limits as the temperature may fluctuate very high as in Figure 4, with little chance of re-cooling. The temperature in the container sometimes varies from 15 to 20 degrees [31,32].

![Figure 4. Changes in temperature during the cold chain [32].](image)

4. Traceability
Traceability is the ability to access any or all information related to what is being considered, throughout the cycle through identification and recording recorded in the system [33]. Maintaining and recording is an integral part of good farm practices. Regularly maintained and monitored records of each or every herd from farm to delivery for slaughter or sale in the market are essential to tracing back the origin of the animal in case of an emergency [34]. Traceability is applied to the meat cold chain system to ensure products can be tracked and traced. Tracking is the ability to follow the downstream path of a product along the supply chain, while tracing refers to determining the origin and characteristics of the product referring to records stored upstream of the supply chain [35]. This traceability can monitor the level of product halalness from upstream to downstream.

The advantages of implementing this system increase product safety and reduce risks to consumer health. These advantages include improving control and monitoring the real-time process linking the final product to the raw material. This condition allows the comparison of various raw materials for quality control purposes and provides information when product recalls occur. The traceability system is able to assist the audit process [36]. Several tracing and tracking technologies have been introduced to the meat industry. These technologies include barcodes, microcircuit cards, radio frequency tags and transponders (RFTT), radiofrequency tags, voice recognition systems (VRS), bio coding, and chemical markers [37]. In addition, radio frequency identification (RFID) has been widely developed for supply chain traceability systems.

5. RFID application in halal beef cold chain
RFID (Radio Frequency Identification) is the latest technology that automatically tracks objects remotely via radio frequency. The advantage of the RFID system is that it can identify in real-time with high accuracy and monitor the location of objects continuously. RFID manages real-time data accurately [38]. The frequency of an RFID system determines its cost, range, and application variance. Systems using low frequency have a low price but low usage distance. Higher frequencies provide longer reading distances and faster readability. RFID uses radio waves between the frequencies of 30 kHz and 5.8 GHz [39].
A simple RFID system includes three main components: a tag, a reader, and a computer or enterprise system, such as Figure 5. The tag consists of a small microchip and antenna and can be attached to an object such as fresh or processed meat. Tags have different shapes and sizes and have data storage memory. Specific stored data consist of identification number, product price, product location, date of manufacture, current inventory, type, description, dimensions, and so on [40]. The RFID reader consists of four components: the antenna, the RFID interrogator, the processor, and the user interface. The antenna and interrogator work to collect and decode information from the RFID tag to be passed on to the processor. The processor retrieves tag-related information from the database and displays it in the interface. To improve the adaptability of the whole system, the core components are divided into two groups that operate independently. The antenna and interrogator belong to one group and the processor and interface to another. The interaction diagram between RFID reader components can be seen in Figure 6 [41].

![Figure 5. Components of RFID system [40].](image)

![Figure 6. Core components of an RFID reader [41].](image)

The development of RFID in the meat cold chain cannot be separated from its use in the food supply chain. RFID tags are used to identify temperature, humidity, time, and distance sensors from the slaughterhouse to the consumer. Tags with identification codes can transmit sensor data that has been measured. This traceability system can automatically capture product identity information, properties, and related data (e.g., temperature history), giving the management system a complete description of product status in the cold chain. The use of traceability systems such as RFID does not directly improve quality. Still, if combined, a quality system can associate to each lot of product information about sensory, health, nutritional, composition, or process attributes that may assign specific and individual economic value [42].

Several studies of the application of RFID for traceability are used in meat from farming to shipping. Hu et al. [43] utilized RFID combined Electronic Product Code (EPC) and Baidu Map API to form a traceability and tracking platform to improve service and food safety in the food life cycle. Barge et al.
[44] utilize RFID as a traceability system for animal identification and tracking on farms and slaughterhouses to meet regulatory and supply chain management requirements. Feng et al. [45] used RFID to identify cattle, acquire breeding data, and transmit traceability data. The evaluation results show that RFID in-ear labels with a frequency of 13.56-900 MHz are needed to track cattle from breeding to slaughtering. Information in the RFID ear label is related to feeding, medical treatment, ante-mortem inspection status, information about cattle carcase, information of the segmented beef, and weight and name of the beef product. Mousavi et al. [37], reported the use of RFID combined with intelligent conveyor systems for meat packaging. The carcass is hung on the hook before starting the process of passing through the intelligent conveyor. Each hook has an RFID tag containing a unique code as an index to a database that stores the tracing history of the animal from the farm to that point and facilitates updating of production data if needed. This identification is unique to each carcass and is used only in processing facilities. As the carcass goes through processing, additional RFID tags are programmed and attached to each carcass component. Grande and Vieira [46] combined RFID with EPC in meat packaging. RFID reads labels on hooks, trays, and labels on packaged meat. The labels on the hooks, trays, and packaging are passive RFID and contain an EPC identification code. This label contains all phase information of the animal production process for storage and shipping control. Readers installed in strategic locations then identify tags in their coverage area and send information to the middleware connected to them. The information is gathered to the application for client access. According to Ruhanen et al. [47], RFID offers the advantage of automatically monitoring the storage conditions of marked products during storage and transport. This condition promises shippers and consignees to monitor and evaluate the quality, safety, and halalness of products during the cold chain. Various practical research on the use of RFID combined with other technologies needs to be continuously developed to monitor product conditions in real-time.

6. Conclusions
The application of RFID-based traceability is an efficient and effective alternative to monitor the quality, safety, and halalness of beef during distribution in the cold chain in real-time from slaughterhouse, distribution, retail, and consumer. A simple RFID system includes three main components: a tag, a reader, and a computer. This system uses a frequency of 30 kHz - 5.8 GHz. Information stored in RFID includes cattle passport databases and electronic data from markets, slaughterhouses, third-party agents, other organizations involved in distribution, temperature, humidity, time, and distance sensors from the slaughterhouse to the consumer. Several studies have combined RFID with EPC to maximize tracking ranging from breeding, slaughtering to meat packaging. Information on RFID related to feeding, medical treatment, ante-mortem inspection status, information about cattle carcase, knowledge of the segmented beef, and weight and name of the beef product. The amount of important information that can be accessed promises shippers and consignees to monitor and evaluate the quality, safety, halalness of products during the cold chain. Various practical research on RFID combined with other technologies needs to be continuously developed to monitor product conditions in real-time.

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