Building Transparency through Halal and Qualified Traceability System of Beef Distribution in Malang City, Indonesia

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Abstract. Halal and qualified beef are essential needs for Indonesian people. Simple and valid monitoring technology must be developed to ensure halal and qualified beef. This study aims to design a Radio Frequency Identification (RFID) traceability system for halal and qualified beef during distribution. The halal beef data is recorded on the RFID tag, while the qualified beef is monitored in real time through temperature, humidity, and the distribution car position. The design uses LM35, DHT11 sensors, Global Positioning System (GPS) modules, and RFID tags. Tests of the sensor's accuracy, validity, and stability were carried out in three replications. The results show that the average temperature and humidity sensors differed by ±3% accurate, valid, and stable. The simulation showed that the product's information, namely the sender's identity, destination, recipient, weight, type of cut, delivery time, time of receipt, and halal status, can be recognized by different RFID tags and displayed on the dashboard. The root Mean Square Error (RMSE) of the beef distribution vehicle's position of 0.1290 was accurately monitored using a GPS module. The RFID traceability system design can accurately and real time monitor integrated halal and qualified beef during distribution.

Keywords: Beef; GPS; Halal; RFID; Sensor; Traceability

1. Introduction

Guarantee of halal products includes the provision of materials, processing, storage, packaging, distribution, sales, and product serving. Implementing halal product guarantees is vital in line with food safety and quality. Consumers want their products to be guaranteed. Therefore, traceability is applied to monitor the product supply chain. Traceability has three components: tracing, tracking, and product movement history (Bosona and Gebresenbet, 2013). Traceability is the ability to follow and study every activity related to the supply chain through early detection to prevent unqualified products from reaching consumers (Millard et al., 2015). Quality and halalness traceability systems in the supply chain need information transparency. The attention of consumers and the government toward health, safety, authenticity, and halalness was the background for implementing traceability as an efficient system to integrate and track all processes in complex supply chains (Mishra et al., 2015).

Traceability as a system based on the Internet of Things (IoT) presents various things in a network that can communicate and interact, working together for the same goal (Sobral et al., 2018). Traceability acts as a tracking and communication tool that provides a wealth of information about a product, such as origin, processing, handling, and related activities, during and after the supply chain (Haleem et al., 2019). The basic traceability system consists of three components: data identification, database management system, and data exchange (Patidar et al., 2021). One of the traceability devices in the IoT-based halal food logistics system is RFID. RFID is a contactless technology that automatically identifies objects, animals, and people using radio waves (Alfian et al, 2020). RFID requires a reader and a tag attached to track the product (Sun, 2012). There were many research on traceability based on RFID, such as kiwi fruit supply chain (Gautam et al., 2017), fresh vegetables supply chain (Mainetti et al., 2013), recording the storage of wheat flour (Qian et al., 2012), monitoring Italian cheese quality (Papetti et al., 2012), agricultural food products to prevent contamination (Farooq et al., 2016), wine treatment on production stage (Expósito et al., 2013), cold chain logistic (Trebar, 2015), recording farm and animal information on beef packages (Buskirk et al., 2013), and real time tracking agricultural food supply during transportation (Bhutta & Ahmad, 2021).

More research is needed on RFID technology with integrated halal and qualified beef tracing. The RFID can accurately and continuously monitor object in real time (Syahputri, 2021). Therefore, this study combines RFID with halal to focus on the distribution from slaughterhouses to industrial consumers, providing transparent information on beef quality and halalness. This system monitors the vehicle's position in real time and changes in temperature and humidity during distribution because beef is very perishable. This real time monitoring is to avoid contamination that decreases beef quality. RFID tags are used to verify the halal status of the product. RFID tag provides detailed information about sender, destination, recipient, weight, type of beef cut, delivery time, time of receipt, and the product's halal status. This RFID tag distinguishes halal and non-halal beef.

Tracking technology using RFID combined with GPS in Indonesia has yet to be widely applied to monitor the quality and halalness of the beef supply chain. Ministry of Agriculture (2018) stated that Indonesian beef consumption in ASEAN is 48% per capita or 2.6 kg. According to SNI 99003:2018 (BSN, 2018), halal products must not be mixed with non-halal products during handling and transportation. This research aims to design a traceability system that makes it easier for the slaughterhouse and consumers to monitor the quality and contamination of non-halal beef during distribution to the processing industry or traditional markets.

2. Methods

This research begins a literature study on traceability, halal food, supply chains, RFID, and Arduino. Next, quality and halal supply chain problems, especially during distribution, are identified, and the variables that affect the quality and halalness are determined. Hadi (2019) stated that various sensors, including temperature and humidity sensors, have been developed alongside RFID. This problem identification process is carried out through an interview with the slaughterhouse, and problem identification focuses on the distribution process. Distributing beef from slaughterhouses to consumers still uses a simple recording system. This recording is only limited to the location where the meat is sent. The unavailability of complete records regarding detailed information about sender, destination, recipient, weight, type of beef cut, delivery time, time of receipt, and the product's halal status makes it difficult for the slaughterhouse to track and trace during the distribution process. Furthermore, this research designed the RFID traceability system with temperature, humidity, and GPS sensors. The Arduino IDE computerized system with the C/C++ programming language is developed. After testing the system, validation was carried out to determine the accuracy of the system design compared to the field data. Data is recorded on a web server database and accessed via a laptop or smartphone. Documentation of monitoring obtained from exporting data via a laptop or smartphone. This document is a guide to help resolve issues during the beef distribution. The research design can be seen in Figure 1.

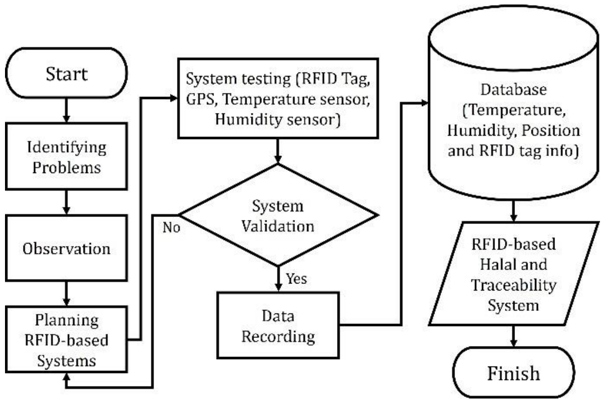


Figure 1 Research Diagram of Halal and Qualified by RFID Design

2.1. Research Variable and Instrument

The traceability system of beef distribution is to maintain quality and halalness. RFID makes it easy to track products during distribution to decide on product recalls due to decreased quality or mixed with non-halal products. The research variables are shown in **Table 1**. The RFID research instrument is used to interface a laptop; the microcontroller is Arduino UNO; the Input consists of NodeMCU ESP8266, 11 RFID tags, RFID reader, LM35 Sensor, DHT11 Sensor GPS Neo 6M Module; the software uses Arduino IDE and Adafruit IO.

Table 1 Research variables of RFID-based traceability system distribution activities

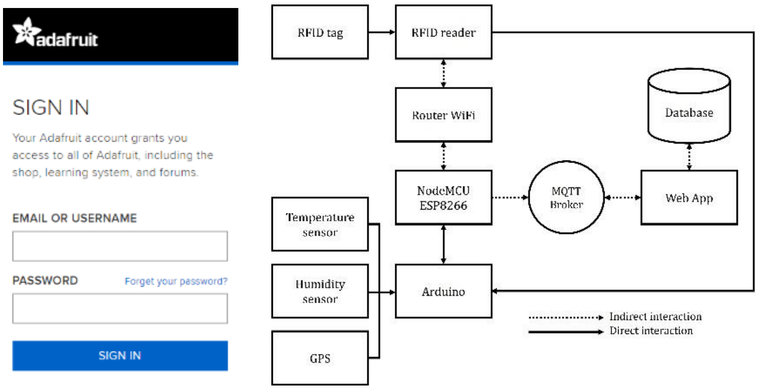
Research Variable	Category	Data Type
Temperature	Primary	Quantitative
Humidity	Primary	Quantitative
Position (GPS)	Primary	Quantitative
An RFID *tag* (sender, destination, receiver, weight, cut type, delivery time, receive time, and halal status)	Primary	Qualitative

2.2 System Planning

The results of the interviews show that the slaughterhouse has not implemented a tracking system for product control during distribution. Therefore, an RFID-based traceability system will help slaughterhouses monitor temperature, humidity, and vehicle location using a GPS sensor and module during distribution. The design of system connections, sensors, and GPS modules is described in this sub-chapter.

<u>2.2.1 System Connection Input Design</u>

Synchronize traceability system programming script inputs on Arduino IDE with Arduino UNO microcontroller, NodeMCU ESP8266, Arduino system store, and RFID to ensure data exchange that data can be displayed on the dashboard in real-time. The script is written in the Arduino programming language to connect a modem or wireless local area network (WLAN) device to receive internet data networks. The internet transmitter and receiver from the modem on the Arduino UNO are the NodeMCU ESP8266. The modem or WLAN device is registered on the Arduino system. The system stored is an input for receiving data networks to be connected to the internet so they can sign in on the adafruit.io website as a Message Queuing Telemetry Transport (MQTT) broker. The database is automatically recorded in the system. The sign-in display on the adafruit.io website and the work scheme of the RFID system in this study can be seen in Figure 2.



(a) (b)

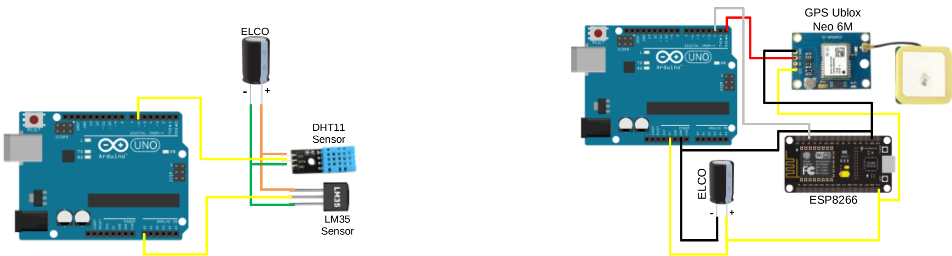
Figure 2 (a) Sign in to adafruit.io; (b) RFID system working scheme

<u>2.2.2 RFID Reader and Tag Design</u>

The RFID reader is RFID-RC522 and the tag is a keychain. The RFID reader component reads product info stored on the tag. Data received by a reader is processed with the help of NodeMCU ESP8266, which is supported by the WLAN network not only to control functions of connected components, read the information on RFID tags, but also process data from the module, and display it on the dashboard (Chin et al., 2022).

<u>2.2.3 Sensor and GPS Component Design</u>

The LM35 and DHT11 sensors used for temperature and humidity readings are connected to the Arduino UNO board with wiring, as shown in Figure 3a. A capacitor is added to store electric current and filter voltage in this circuit. These capacitors are used when a large capacitance is required. The capacitors used electrolytic capacitors (ELCO). ELCO are widely used because they have a fixed value and polarity (poles + and -) (Gudavalli & Dhakal, 2018).



(a) (b)

Figure 3(a) LM35 and DHT11 Sensor Circuits on Arduino UNO; and (b) Ublox Neo 6M GPS Circuit on Arduino UNO

The Ublox Neo 6M GPS module to read the vehicle position is connected to the Arduino UNO and ESP8266 boards with wiring (Figure 3b). This GPS module can receive data from latitude and longitude and display it on a map. The ESP8266 transfers position coordinate data via the internet network, stores position data in a database and displays it on the dashboard within 1 minute.

2.3 System Validation

Validation tests measure the precision and accuracy of the tool. If the validity is higher, the device is closer to the standard. Car position validation is assessed with Root

Mean Square Error (RMSE), while temperature and humidity validation uses error percentage.

2.3.1 Position Validation (GPS)

Validation test of distribution vehicle's position using RMSE. RMSE calculates the geometric accuracy or degree of uncertainty of the object's position coordinates. RMSE measures the accuracy of several digitized points in the image with the same number of points in the field, and it shows the forecast error for a specific data set (Rachmanto & Ihsan, 2020; Hendrarini et al., 2021). The RMSE is shown in Equation 1.

$$\text{RMSE} = \sqrt{\frac{\Sigma(Y-Yi)^2}{n}} \tag{1}$$

Where Y is the actual value, Y_i is the forecast value, and n is the amount of data.

RMSE calculation is the distance traveled (location point) time during the beef distribution by GPS. The delivery time from the start point of the vehicle's departure to the endpoint is recorded to calculate the RMSE. RMSE allows comparing estimated and measured values term-by-term, indicating short-term model performance. Smaller values mean better performance (Kambezidis, 2012). According to Fitriawan et al. (2020), the RMSE ≤0.33 indicates that the prediction is more accurate than the observed.

2.3.2 Temperature and Humidity Validation

Humidity validation is determined by calculating the error and percentage by comparing sensor readings with a Thermohygrometer as a test standard. The value and percentage error are computed using Equation 2 (Isyanto et al., 2021).

$$\%\text{Error} = \left|\frac{X-Xi}{X}\right| \text{x } 100\% \tag{2}$$

where X is the actual value from the Thermo hygrometer and X_i is the measured value from the sensor reading.

If the error is known, the sensor can assess its feasibility. An error above 7% makes the sensor declared unfit and needs calibration. Large errors affect the prototype's accuracy and the response to sensor readings (Nasution & Harahap, 2020).

3. Results and Discussion

This sections discuss the validation, testing results, and simulation of the halal and quality system using RFID tags and its development implications. The data will be displayed on the dashboard if the tag functions correctly.

3.1 Temperature and Humidity Sensor Testing

Testing and validating the LM35 and DHT11 sensors for temperature and humidity were carried out by comparing the recorded sensor reading data stored in the database against the standard. Standard temperature results from a digital thermo-hygrometer—sensor testing for two hours outdoors without treatment in a stationary condition for three days. The recording of temperature changes is carried out manually every 15 minutes. The average of the DHT11 and LM35 sensor errors is shown in **Table 2**.

Table 2 Calculation of the DHT11 and LM35 sensor average error

Time (WIB-Indonesian Time)	Average Temperature Error		Average Humidity Error
	LM35 Sensor	DHT11 Sensor	DHT11 Sensor
Day 1, time 22.00-00.00	2%	3%	2%
Day 2, time 00.00-02.00	1%	1%	2%
Day 3, time 23.00-01.00	2%	2%	2%

Based on Table 2, the largest average DHT11 sensor error on the first day was 3%, and the smallest on the second day was 1%. The average LM35 sensor error is the smallest on the second day at 1%. The average error shows that the DHT11 and LM35 sensors for temperature readings are valid and can be used. According to Nasution & Harahap (2020), an error above 7% makes the sensor unfit and needs calibration. The temperature and humidity readings of the DHT11 and LM35 sensors are also stable (Table 3). The average temperature is not significantly different. The largest difference is $\pm 1^oC$. The average humidity differed by ±3%. Changes in temperature and humidity on the device have been limited to readings on the web dashboard.

Table 3 Average sensor readings LM35 and DHT11

Time (WIB-Indonesian Time)	Average temperature (^0C)		Average humidity (%)
	LM35 Sensor	DHT11 Sensor	DHT11 Sensor
Day 1, time 22.00-00.00	23.7	25.2	71
Day 2, time 00.00-02.00	24.5	25.3	74
Day 3, time 23.00-01.00	24.9	25.9	72

3.2 GPS Tracking and Validation

The position of the beef distribution vehicle is tracked using the Neo 6M GPS module, which is connected to the internet network from a modem. Neo 6M GPS module functions to receive the coordinates of a device located when the indicator light on the module blinks and detects position by reading latitude and longitude (Kharisma et al., 2019). Recording of location points is done within 1 minute. Beef delivery is 2.37 km for 13 minutes. The final destination of the beef shipment is tracked in real-time to the Malang traditional market at 17.53 UTC (+7) or 00.53 WIB with coordinates -8.023411, 112.630361. Google Maps measures the distance the vehicle departs at the beef distribution destination in Figure 4. The coordinate points recorded in the database are inputted on Google Maps, and the distance between points is measured using the distance menu. The point data (lat, long) and the distance of beef distribution are shown in Table 4.

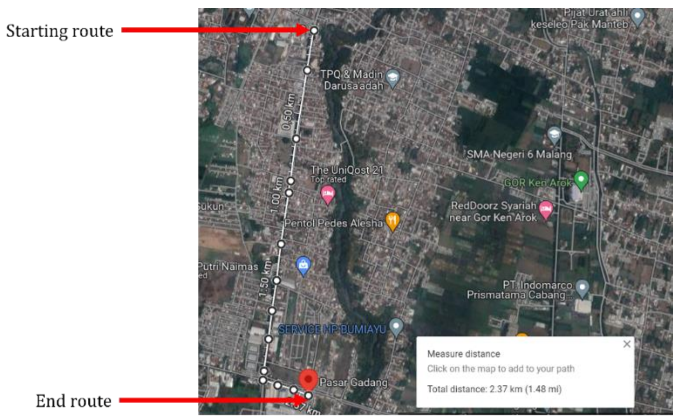


Figure 4 Distance measurement from starting to end point of beef delivery

Table 4 Data points and distances for beef distribution locations

Date	Time (UTC)	*Latitude*	*Longitude*	Distance (km)
11-05-2022	17:40:23	-8.0043	112.629962	0
11-05-2022	17:41:11	-8.0063	112.629968	0.24
11-05-2022	17:42:22	-8.0098	112.629465	0.65
11-05-2022	17:43:10	-8.012	112.629186	0.90
11-05-2022	17:44:22	-8.0125	112.629035	0.97
11-05-2022	17:45:10	-8.0154	112.628604	1.28
11-05-2022	17:46:21	-8.0173	112.628229	1.50
11-05-2022	17:47:09	-8.019	112.628052	1.68
11-05-2022	17:48:20	-8.0205	112.627891	1.85
11-05-2022	17:49:08	-8.0223	112.627707	2.05
11-05-2022	17:50:20	-8.0228	112.628048	2.13
11-05-2022	17:51:08	-8.0229	112.628907	2.23
11-05-2022	17:52:19	-8.0233	112.629859	2.33
11-05-2022	17:53:07	-8.0234	112.630361	2.37

The RMSE is used for position validation with geometric accuracy. RMSE analyzes the error calculation of several digitized points in the image with the same points in the field (Wibisono & Setiawan, 2015; Rachmanto & Ihsan, 2020). According to Fitriawan et al. (2020), RMSE 0.33 indicates accurate prediction. The RMSE of distance and time of delivery refers to Table 5. Figure 5 is a linear regression of the distance to time.

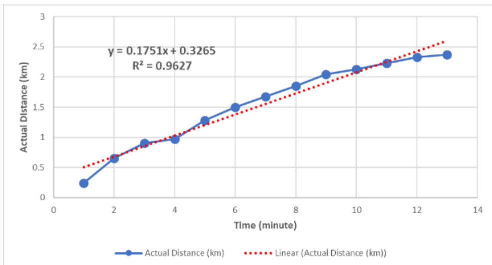


Figure 5 Graph of actual distance against delivery time

Table 5 RMSE of distance and delivery time

Time (minute)	Actual distance (km)	Forecast Distance (km)	Residual	$(\text{Residual})^2$
1	0.24	0.50	-0.26	0.068
2	0.65	0.68	-0.03	0.001
3	0.90	0.85	0.05	0.002
4	0.97	1.03	-0.06	0.003
5	1.28	1.20	0.08	0.006
6	1.50	1.38	0.12	0.015
7	1.68	1.55	0.13	0.016
8	1.85	1.73	0.12	0.015
9	2.05	1.90	0.15	0.022
10	2.13	2.08	0.05	0.003
11	2.23	2.25	-0.02	0.000
12	2.33	2.43	-0.10	0.009
13	2.37	2.60	-0.23	0.054
			RMSE	**0.1290**

Coordinate accuracy is obtained by residual measurement data in the field in the form of coordinates GPS measurements and coordinates from satellite images. The residual value of the X and Y coordinates is used to find the RMSE (Kurniawan et al., 2015). The X-coordinate is the actual distance on Google Maps satellite imagery, while the Y-coordinate is model forecasting using linear regression from GPS measurement data. Linear regression assumes that changes in one variable are accompanied by other variables (Bazdaric et al., 2021). The position validation from the initial coordinates to the beef delivery point obtained an RMSE of 0.1290. The RMSE of ≤0.33 indicates an accurate model against the actual distance. The GPS module can be used to monitor beef shipments in real time.

3.3 Simulation of Halal and Other Information with RFID Tag

In the future, the RFID tag in this research is for all possible products: carcass, non-carcass, and offal packaged. The keychain-shaped tag was chosen for easy attachment to the packaging. It provides ten tags containing product-related information, each with a different code. However, the simulation used six tags: two for halal products, two for products without a halal certificate, and two for haram products.

The info on the tag is sender, destination, recipient, weight, type of beef cut, delivery time, time of receipt, and the halal status carried out by the slaughterhouse. Input product info on the tag is simulation data. This simulation mixes products previously given with RFID tags that contain halal, haram, and unclear product info to determine if the system can distinguish the info.

Tag 1 and Tag 3 are halal products (tag codes 83CCCC73 and D0121FC3). Tag 6 and Tag 10 are for products with no halal certificate (tag codes 5B671EC3 and 82E420C3). Tag 5 and Tag 7 for haram products (tag codes 549948D3 and 755146D3). The tag is attached to the product in the carcass distribution room and tagged on the reader. When the tag has been read and entered into the system, the tag code appears on the ID dashboard, and the tag info is on the RFID dashboard. Tag info is shown in Figure 6.

(a) (b)

Figure 6 System simulation: (a) RFID tag code and (b) RFID tag info

The system can read and recognize product information tags and display them on the dashboard. The result means that the system can report contamination if a halal, haram, or unclear product is together in the vehicle. Halal traceability in beef distribution is vital to halal beef assurance.

3.4 Beef Delivery Temperature and Humidity Record

The recording of humidity and temperature sensors when shipping is shown in Table 6. The total delivery time from the slaughterhouse to the market is 13 minutes, with a recording period every 1 minute. Data is taken directly at 00.40-00.53 WIB (Indonesian time) or 17.40-17.53 UTC (Universal Time Coordinated).

Table 6 Temperature and humidity readings during beef delivery without cold storage

Date	Time (UTC)	Temperature (^{0}C)		Humidity (%)
		DHT11	LM35	DHT11
11-05-2022	17:40:19	28.1	28.8	73
11-05-2022	17:41:07	28.1	29.3	72
11-05-2022	17:42:18	29	29.3	72
11-05-2022	17:43:06	29	28.8	73
11-05-2022	17:44:18	29	28.8	73
11-05-2022	17:45:05	29	29.3	72
11-05-2022	17:46:17	28.1	29.3	72
11-05-2022	17:47:05	29	29.8	71
11-05-2022	17:48:16	29	29.8	71
11-05-2022	17:49:04	29.1	29.3	72
11-05-2022	17:50:16	29	29.3	72
11-05-2022	17:51:04	29.1	29.3	72
11-05-2022	17:52:15	29.1	29.8	71
11-05-2022	17:53:03	30	29.8	71

Humidity is related to temperature, which determines beef quality during shipping. Humidity is inversely proportional to temperature, so every increase in temperature occurs in molecular condensation, which decreases humidity (Prakoso, 2018). According to the FDA (2017), raw beef needs cold storage and should not be left at room temperature for more than two hours or at least one hour if the temperature is 90^{o}F or 32^{o}C. Based on the temperature and humidity sensor readings and the short delivery time by car without cold storage, beef is still relatively safe and can be considered qualified beef. On the other hand, beef should be stored and delivered at cold temperatures below 4^{o}C (chilling) or frozen below -18^{o}C (freezing). Cold storage below 4^{o}C makes beef last 3-5 days, while frozen storage below -18^{o}C beef lasts 4-12 months (Jakubowski, 2015). Delivering beef in refrigerated cars can help inhibit microorganisms' growth.

In this research, beef delivery was conducted without cold storage. However, based on calculations and simulations, the system is valid for identifying halal and qualified beef. The RFID-based halal and qualified traceability system in this research can be applied to monitor meat distribution, including cold storage, for future development. Further research needs to test this system in cold storage to identify weaknesses and improve it.

3.5 Implication on Halal and Qualified Traceability System Development

The RFID-based halal and qualified traceability system in this research can be applied to monitor beef distribution. However, based on calculations and simulations, the RFID system was valid for identifying halal and qualified beef delivery without cold storage. Further research can potentially develop and test this system in cold or freeze-storage beef distribution cars in a long supply chain. RFID has several obstacles: data transmission delays, unstable networks, and wiring that need to be improved by an antenna to capture a more robust and better signal. Other indicators, such as LED lights, can be added as a marker for vehicle drivers if the temperature and humidity have exceeded the limit.

4. Conclusions

The RFID-based integrated halal and qualified beef traceability system focuses on distribution from slaughterhouses to industrial consumers. The beef average temperature and humidity sensor differed by ±3%, and the GIS module has an RMSE of 0.1290 valid. Simulation can recognize tags with different product information, including haram on halal materials, and display it on the dashboard. The RFID system in this research was conducted in a vehicle without cold storage, so further research is required to test in cold and freeze storage to improve it. If the temperature and humidity are exceeded, the RFID system can add an antenna to signal reception and LED lights in vehicle drivers.

Acknowledgements

The study received funding from the Faculty of Agricultural Technology, Universitas Brawijaya, in 2021 under a doctoral grant [No. 1615/UN.10.F10/PN/2021].

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