

Design and Build a Quail Cage Monitoring and Control System Using IoT-Based Research and Development (R&D) Methods

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ABSTRACT: Technological developments in the modern era have encouraged various innovations in the livestock sector, one of which is through the implementation of internet-based systems that allow management to be carried out more efficiently and integrated. One of the applications is that quail farming is a type of poultry that has high economic value, but its maintenance is still constrained by monitoring and controlling the cage environment which is carried out manually, so it has the potential to cause stress, suboptimal growth, and death. Therefore, this study aims to design and build a monitoring and control system for quail cages based on the *Internet of Things* (IoT) during the brooding period of 3–16 days, as well as compare IoT cages with conventional cages. The method used is *Research and Development* (R&D) which includes the design, manufacture, and testing stages of the system. The system is developed using the ESP32 microcontroller which is integrated with DHT22, MQ135, and BH1750 sensors, and is supported by SERVO MOTOR and WATER LEVEL sensors. Based on the results of the study, the system is able to maintain environmental conditions with an average temperature of 31°C, ammonia content of 10 ppm, and humidity of 83%, and is able to conduct monitoring and control in real-time well. In addition, the implementation of the system has a positive impact on quail growth, with an increase in daily body weight (PBBH) of 2.14 g/day (73.5% higher), feed consumption of 1191 g (4.93% higher), and FCR of 3.52 (34.6% more efficient) compared to conventional cages, so that the system has proven to be effective in increasing the maintenance efficiency and productivity of quails.

KEYWORDS: Internet of Things (IoT) Quail Monitoring Cage ESP32 Feed Conversion Ratio (FCR)

I. INTRODUCTION

The development of technology in the modern era encourages innovation in the livestock sector, one of which is through an internet-based system that allows for more efficient and integrated management [1]. The Internet of Things (IoT) is growing rapidly and provides opportunities in monitoring and control in the field of livestock [2]. However, quail maintenance is still largely done conventionally, causing obstacles in monitoring and managing cages [3]. In addition, quail farms have an important role in providing food and economic opportunities [4]. Quail (*Coturnix coturnix*) has a high production potential of up to more than 300 eggs per year [5]. Its productivity is greatly influenced by environmental conditions such as temperature, humidity, lighting, and ammonia levels. At starter, the ideal temperature is 30–38°C and humidity is 30–80% [6][7]. Light intensity 60 lux [8]. and ammonia levels <25 ppm [9]. As technology has evolved, various studies have developed IoT systems, such as the use of NodeMCU and Blynk [10][11] as well as microcontroller integration for monitoring [12]. However, the study is still limited to the monitoring aspect without comparative testing and has not yet integrated multi-sensor-based automatic control. Therefore, this study aims to design an IoT-based quail cage monitoring and control system and compare it with conventional cages using Research and Development (R&D) methods [13].

II. RESEARCH METHODS

The research methods used in this study are *Research and Development* (R&D), which is a method used to produce and develop products and test their effectiveness so that they become more efficient, effective, and productive [14]. This method was chosen because the research aims to design, build, and test a quail-based monitoring and control system *Internet of Things* (IoT).

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Figure 1. Methods of R&D

The development model used refers to the Sugiyono model which consists of several stages, including identification of potentials and problems, data collection, product design, product revision, field trials, and product finalization. The problem identification stage was carried out in conventional quail cages that still experienced difficulties in monitoring temperature, humidity, ammonia levels, and lighting. Furthermore, data collection was carried out through a literature study related to IoT-based monitoring systems. The system design was carried out by building an ESP32 microcontroller-based system that is integrated with DHT22, MQ135, LDR, and water level sensors, and is equipped with automatic control using relays and servo motors through the MIT App Inventor-based mobile application. The test stage is carried out in a real enclosure to observe system performance, sensor accuracy, and actuator response. Furthermore, product finalization is carried out based on test results to ensure that the system works optimally in supporting quail rearing. The use of ESP32 microcontroller-based architecture enables precise sensor integration, allowing environmental data to be processed in real-time and monitored remotely to minimize inefficient manual intervention [15]

A. System Needs Analysis

Table 1. Hardware requirements

Yes	Component name	Function	Quantity
1	ESP32 + Expansion Board	Main microcontroller	2
2	DHT22 Sensor	Measuring temperature and humidity	1
3	MQ135 Sensor	Detecting Ammonia gas in the cage	1
4	BH1750 sensor	Measuring light intensity	1
5	16 x 2 LCD	Data viewer from sensors	1
6	Relay 6 cahanel	Switch the mini water pump lights and fan according to the sensor reading	1
7	Bholam lamp	As a heating and lighting room	2
8	12 volt DC fan	As a supplement to the cycle and ventilation of the cage	2
9	Jumper Cable	Liaison between ranks	1
10	12V 2A Adapter	Power transmitter for the fan	1
11	RTC	Lag/time controller for feed	1
12	Servo Motor	As a controller, open and close the feed storage place	1
13	Lighting Pitting	As a link between light and electricity	2
14	Plastic Bottles	Containers for feed	1
15	Mini Water Pump	As a drinking water supplier	1
16	Connector Jacks	As a current connection between the connector jack and the cable to the fan and lamp	1
17	Water Level Sensor	As a measure of the level of drinking water, and the water detector has run out or is still	1

Table 2. Software requirements

Yes	Software	Stuttgart
1	Arduino IDE	An integrated software environment that allows users to write, edit, compile (compile code), and upload programs (called <i>sketches</i>) to the ESP32 Arduino IDE.
2	<i>Invent Invent App</i>	As a bridge between the internet-connected physical devices and the digital world, enabling real-time monitoring, remote control of devices
3	<i>Fritzing</i>	Devices for designing and manufacturing electronic circuits
4	<i>Firebase</i>	Firebase is a <i>Backend-as-a-Service</i> (BaaS) service from Google that helps make it easier to create web and mobile applications without having to manually manage servers. Its main functions include storing data in real-time using Firestore or Database.

III. SYSTEM DESIGN

This process involves a comprehensive design of the system architecture to be developed, covering both hardware and software aspects. This includes compiling block diagrams, system flowcharts, network schemas, ESP32 programming, database structures, and designing applications using *MIT App Inventor*. The optimal integration of all design elements is expected to ensure effective system performance.

A. System Block Diagram

The system block diagram shows that the *Internet of Things* (IoT)-based quail enclosure system consists of input, process, and output components. The inputs include a DHT22 sensor to measure temperature and humidity, an MQ135 sensor to detect ammonia gas levels, a WATER LEVEL sensor to measure or detect that drinking water is running out or still full, and a BH1750 sensor to measure light intensity, all of which are connected to the ESP32 microcontroller. The ESP32 acts as a control center that processes data from the sensor, displays information on the LCD, and sends and stores data to Firebase, then forwards the data to the *MIT App Inventor*-based Android application and determines the device's control actions. *Firebase* serves as a data storage medium and a two-way communication link between the system and the user, including automatic mode. The output part is controlled through a relay module that is used to set devices such as heating lights, lighting lights, and fans as air circulation in the cage. In addition, LCD and Android apps are used to display the environment conditions of the enclosure in real-time and allow users to control or monitor the device remotely.

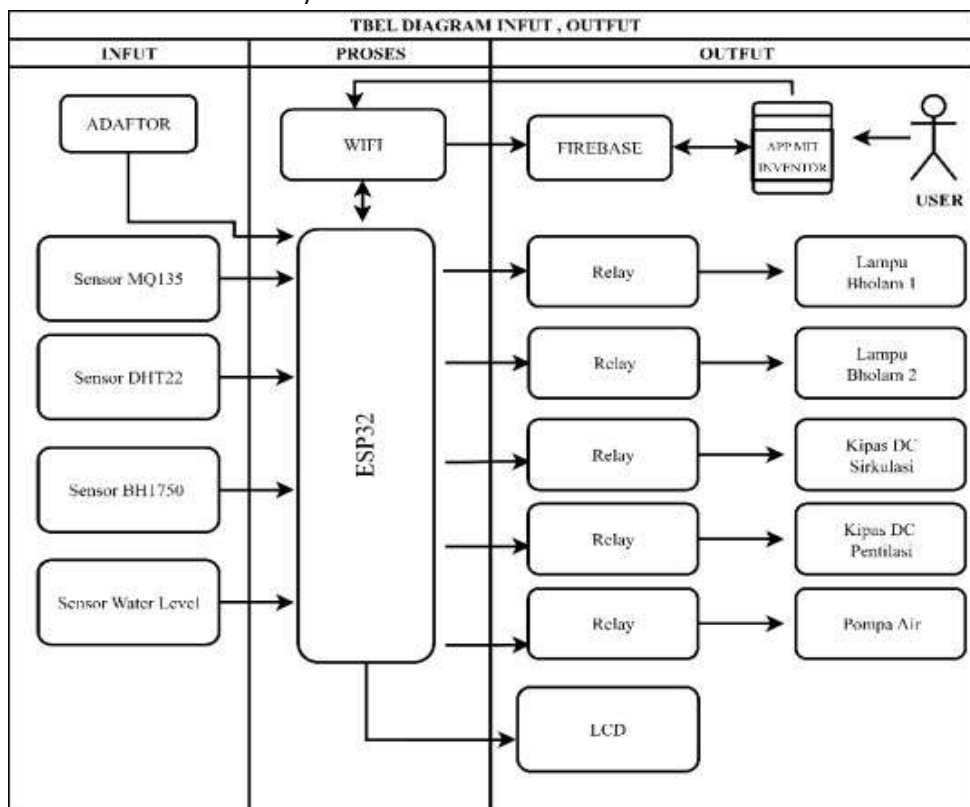


Figure 2. System Block Diagram

B. Network Systems

The system circuit schematic describes the interconnection between the hardware components consisting of the ESP32 microcontroller, the DHT22 sensor, the MQ135, the BH1750, the water level sensor, the relay module, the LCD, and the power source. The system is designed to transmit real-time data on the environment conditions of the enclosure to Firebase and is displayed through the MIT-based Android app App Inventor. Connections between components include digital pins, analog pins, and I2C communications.

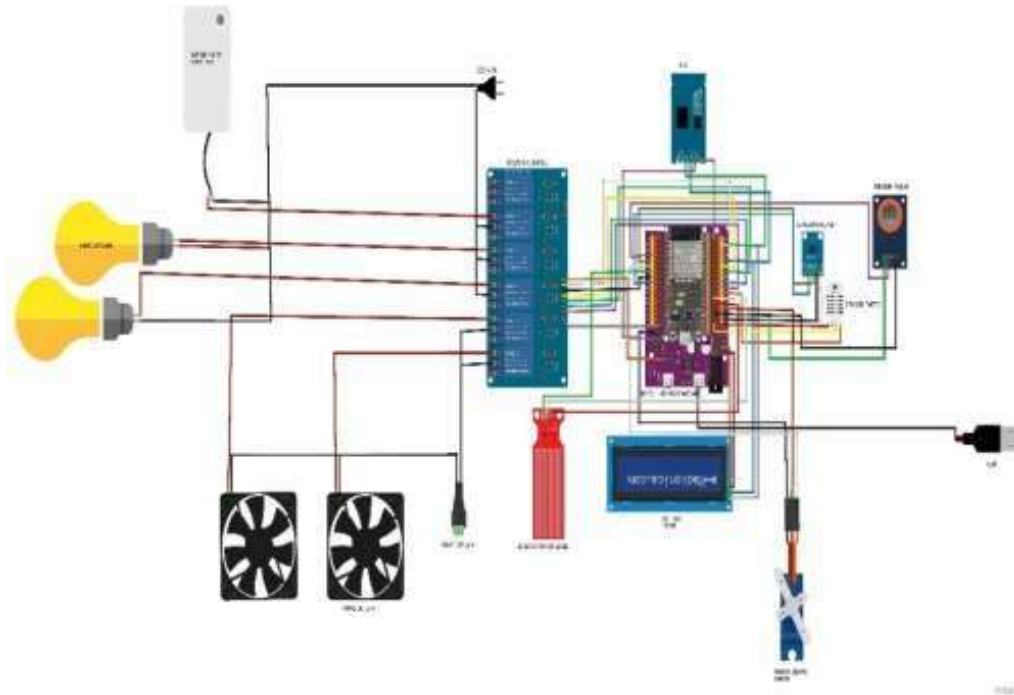


Figure 3. Sitem Network

C. Flowchart flow system

The system flowchart in Figure 4 shows the working stages of the Internet of Things (IoT)-based quail cage monitoring and control system utilizing ESP32, DHT22, MQ135, and BH1750 sensors, water level sensors, Firebase Realtime Database, and the MIT App Inventor application. The process starts with system initialization, then continues with checking the WiFi and Firebase connections. If the connection is not connected, the system will automatically reconnect until it is successful. Once the connection is available, the system reads data from the sensor in the form of temperature, humidity, ammonia gas content, light intensity, and water conditions in the drinking container. The data obtained is then sent to Firebase and displayed via LCD. Next, the system carries out an automatic control process based on the detected parameter values, where devices such as heating lights, circulation fans, ventilation fans, lighting lights, and water pumps will be on or off according to the predetermined value limit to maintain optimal conditions in the cage environment. Any changes to device condition and status will be updated on Firebase and displayed on the LCD and MIT App Inventor app. This process takes place continuously so that the system is able to monitor and control the condition of the cage in real-time and continuously.

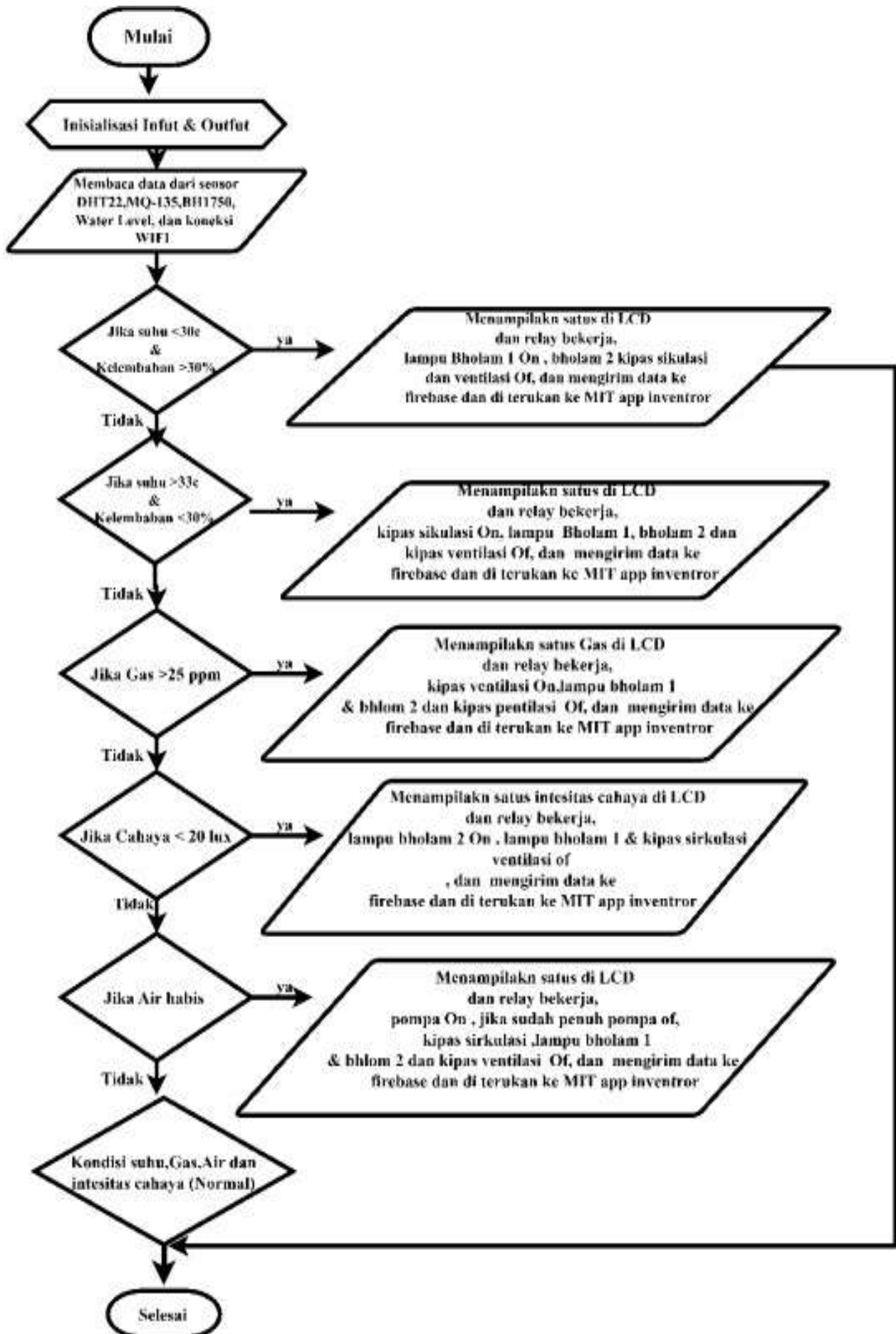


Figure 4. System flow

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IV. RESULTS AND DISCUSSION A. Hardware Exposure

The system hardware has been designed and installed in the quail cage consisting of one temperature and humidity sensor (DHT22), one ammonia gas sensor (MQ135), and one light intensity sensor (BH1750). The system is also equipped with two bulbs with a power of 25 watts and 40 watts that serve as a lighting source as well as heating, which are installed hanging at the top of the enclosure. and at the bottom the WATER LEVEL sensor is installed as an automatic drinking water measuring device that is out or still, and on the outside there is a SEVO MOTOR as an open and close switch for feed and there is a mini pump as an automatic drinking water supplier. In addition, two 12V DC fans are placed on the left and right sides of the cage to support air circulation and keep the temperature stable.



Figure 5. Outdoor and Indoor IoT Enclosure Display

B. Software Implementation

Software design begins after the hardware design is completed, the system software is built with, Firebase and MIT App Inventor. The MIT App Inventor-based app is designed as the main interface that connects users with IoT-based quail cage systems. This application was developed with an emphasis on ease of use so that it can be operated by users simply. The main display presents information on the environmental conditions of the cage, including temperature, humidity, ammonia content, light intensity, as well as the status of devices such as servo and water. Data is obtained from sensors integrated with the ESP32, then sent to the Firebase Realtime Database and displayed in real-time through the app. Apart from being a data visualization medium, the application also functions as a means of remote monitoring to assist users in monitoring the condition of the cage quickly and accurately and ensuring that the control system runs properly.



Figure 6. App Display

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C. Firebase Realtime Database View

The structure of Firebase Realtime Database in this system consists of several main nodes, namely sensor nodes and daily data logs that function to separate data based on its function to make it easier to access, manage, and display on Android applications. Sensor nodes are used to store up-to-date condition data, while daily data log nodes function to store sensor reading history at regular intervals, including temperature, humidity, ammonia levels, light intensity, and device status. This historical data storage allows users to conduct long-term monitoring and analysis of changes in cage conditions more effectively.

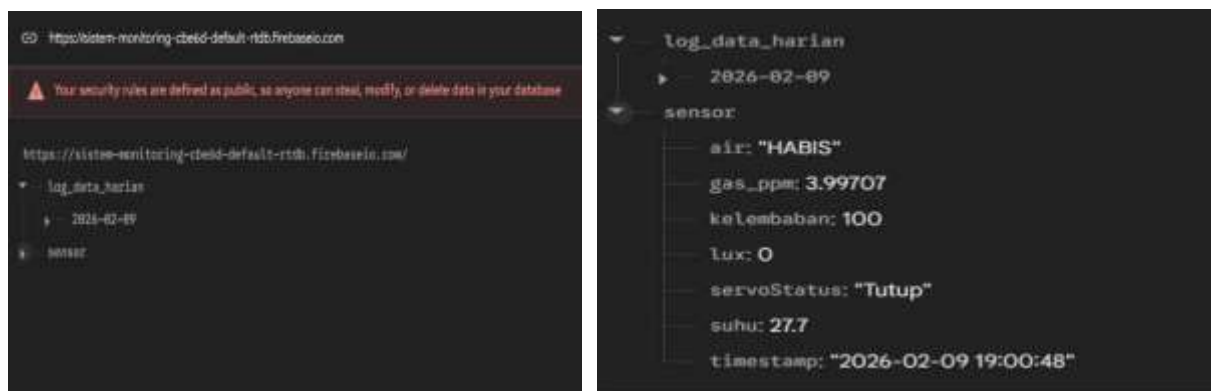


Figure 7. Database Realtime View

D. IoT Enclosure Data and Conventional Enclosure

In Table 3. shows the enclosure environment data with an IoT system that is taken at different times for 24 hours.

Table 3. IoT Enclosure Environment Data

N0	Time (Hours)	IoT Enclosure Conditions						Status
		Temperature (°C)	Humidity (%)	Ammonia (ppm)	Light (Lux)	Water Status	Servo status	
1	00.00	30,1	84,9	6,30	38	Full	Safe	High humidity
2	01.00	30,4	83,3	6,47	67	Full	Safe	High humidity
3	02.00	30,5	84,8	6,75	70	Full	Safe	High humidity
4	03.00	30,1	87,2	8,17	67	Full	Safe	High humidity
5	04.00	29,9	85,3	7,09	67	Full	Safe	High humidity & low temperature
6	05.00	30	83	7,23	67	Full	Safe	High humidity
7	06.00	30	81,8	6,77	65	Full	Safe	High humidity
8	07.00	30,7	85,3	7,18	45	Full	Safe	High humidity
9	08.00	32,5	85,8	9,21	45	Full	Safe	High humidity
10	09.00	33,3	84,9	8,53	60	Full	Safe	High humidity
11	10.00	34,1	84,2	10,10	64	Full	Safe	High humidity
12	11.00	34	80,1	7,0	63	Full	Safe	Secure
13	12.00	33,7	86	8,0	51	Full	Safe	High humidity
14	13.00	35	79	8,3	59	Full	Safe	Secure
15	14.00	34	80	8,7	55	Full	Safe	Secure
16	15.00	34	81	9,7	65	Full	Safe	High humidity
17	16.00	33	79	9,6	66	Full	Safe	Safe

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18	17.00	33	81	12,7	61	Full	Safe	High humidity
19	18.00	32	82	13,5	68	Full	Safe	High humidity
20	19.00	32	83	14,3	43	Full	Safe	High humidity
21	20.00	31	84	16,6	55	Full	Safe	High humidity
22	21.00	31,5	85	17,3	57	Full	Safe	High humidity
23	22.00	31	87	16,7	25	Full	Safe	High humidity
24	23.00	31	86	17,3	49	Full	Safe	High humidity
Average		31,95	83	10	57	Secure	Safe	

E. Conventional Cage

For comparison, measurements were also taken in conventional cages that only used light bulbs as heaters without automatic monitoring and control systems. Data were obtained using an HTC-1 hygrometer placed in a cage. The measurement results show that the environmental conditions are still within the tolerance range with an average temperature of 31°C and humidity of around 67%, but the stability is lower than that of IoT-based enclosures. Figure 8 and the data of the conventional enclosure environment are shown in Table 4.

Table 4. Conventional Cage Enclosure Enclosure

Yes	Time	Temperature °C)	Humidity (%)	Remarks
1	06:29	31.5	66	Safe
2	07:48	30.3	71	Low temperature
3	08:02	30.5	67	Low temperature
4	09:07	30.1	68	Low temperature
5	11:03	32.0	68	Safe
6	14:35	33.5	65	Safe
7	18:06	32.7	66	Safe
8	19:02	32.1	68	Safe
9	19:33	31.8	69	Safe
10	22:08	30.7	72	Low temperature
11	22:47	31	62	Safe
12	23:03	31.7	62	Safe
Average		31	67	Safe



Figure 8. Conventional Enclosure

Although the average temperature value is relatively the same, IoT systems are able to maintain more stable environmental conditions because they are supported by real-time monitoring and automatic control. In contrast, conventional cages cannot be monitored for 24 hours, and in conventional cages, temperature and lighting settings are done manually so that the response to

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environmental changes tends to be slow and heat distribution is less even. This shows that IoT-based systems are more effective in maintaining the stability of the cage environment to support quail growth.

F. Data on the Weight Comparison of the Two Cages

Tests were carried out to determine the influence of the system on quail growth through weight measurement and daily feed consumption during 14 days of maintenance. Each cage was filled with 11 3-day-old quail chicks that were kept with the same treatment, including feeding, cage cleaning, and daily weighing simultaneously, so that the difference in results was influenced by the environmental conditions of the cage. Quail are placed in two types of cages, namely IoT-based cages with automatic monitoring and control systems, and conventional cages with manual methods. To facilitate individual identification and avoid recording errors, each quail is assigned a marker in the form of a different colored bracelet on the leg.

Table 5. Weight Weighing Results of the Two Cages

Ye s	Days / Days	Average Weight – Average		Differe nce (g)	Percentage%
		IoT	Conventional		
1	Sunday 15/2/2026	14	11	3	27,27
2	Monday 16/2/2026	17	12	5	41,67
3	Tuesday 17/2/2026	19	14	5	35,71
4	Wednesday 18/2/2026	22	16	6	37,50
5	Thursday 19/2/2026	23	17	6	35,29
6	Friday 20/2/2026	26	19	7	36,84
7	Saturday 21/2/2026	29	20	9	45,00
8	Sunday 22/2/2026	31	22	9	40,91
9	Monday 23/2/2026	33	23	10	43,48
10	Tuesday 24/2/2026	34	24	10	41,67
11	Wednesday 25/2/2026	36	26	10	38,46
12	Thursday 26/2/2026	38	26	12	46,15
13	Friday 27/2/2026	41	28	13	46,43
14	Saturday 28/2/2026	44	30	14	46,67



Figure 9. Quail Weighing

The test results showed a comparison of quail growth between IoT cages and conventional cages. The average initial weight in IoT cages is 14 g and conventional cages are 11 g. At the end of maintenance, the average weight of quail in IoT cages reached 44 g, while in conventional cages it was 30 g. The total weight gain in IoT cages is 30 g, higher than conventional cages of 19 g. Based on the calculation of Daily Weight Gain (PBBH), IoT cages produce 2.14 g/day, while conventional cages produce 1.36 g/day, with an increase of 73.5%. These results show that IoT-based systems are able to create more stable environmental conditions so as to support quail growth more optimally than conventional methods.

G. Feed Conversion Ratio (FCR) Calculation Results

Based on the calculation of FCR from IoT cages and conventional cages, a difference of 1.86 FCR values is obtained where the FCR value of IoT cages is 3.52, which means that to produce 1 gram of quail body weight is needed around 3.52 grams of feed. Then the FCR in conventional cages is 5.38, which means that around 5.38 grams of feed are needed to produce 1 gram of quail weight gain. From these results, it can be concluded that cages with IoT systems are able to increase feed utilization efficiency by 34.6% compared to conventional cages. With lower FCR values, IoT cages have proven to be more efficient in supporting quail growth than conventional cage systems.

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V. CONCLUSION

Based on the results of the research, the Internet of Things (IoT)-based quail cage monitoring and control system was successfully designed using ESP32 which is integrated with DHT22, MQ135, water level, servo motor, and BH1750 sensors, and is supported by Firebase and MIT App Inventor. The system is able to monitor environmental conditions in real-time and maintain the stability of the cage better than conventional systems. The test results showed that quail growth in IoT cages was more optimal with a daily weight gain value (PBBH) of 2.14 g/day, higher than conventional cages of 1.36 g/day. The total feed consumption in IoT cages is 1191 grams, slightly higher than conventional cages of 1135 grams, but results in better growth. In addition, the Feed Conversion Ratio (FCR) value in IoT cages is 3.52, lower than conventional cages of 5.38, which indicates better feed utilization efficiency. Overall, the IoT system is able to increase the efficiency of feed use by up to 34.6% compared to conventional cages.

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