IoT-Based Duck Egg Incubator with Automatic Turning Feature to Increase Productivity

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A R T I C L E   I N F O

A B S T R A C T

Duck farming has great potential in Indonesia but still faces challenges in achieving high hatching success due to inefficient manual incubation methods. Stable temperature, humidity, and accurate egg-turning schedules are important factors for successful incubation. This study aims to design and develop an (IoT)-based duck egg incubator with an automatic turning feature to increase productivity. The system uses an ESP32 microcontroller, a DHT22 sensor, a DS3231 RTC, and the Blynk application for remote monitoring via smartphone. The research method is engineering-based, including literature study, hardware and software design, prototype development, system testing, and analysis. The incubator has dimensions of 60 × 40 × 40 cm with a capacity of about 50 eggs. The main components include three incandescent lamps as the heat source, a cooling fan, an automatic egg rack driven by an AC motor, and a monitoring system using an LCD and the Blynk application. Testing results show that the incubator maintains an average temperature of 37.9°C and humidity of 62.2%, with standard deviations of ±0.63°C and ±1.90%, which are within the ideal range for duck egg incubation. The DHT22 sensor shows high accuracy, reaching 99.84% for temperature and 99.18% for humidity. The automatic egg-turning system operates according to the scheduled times at 00:00, 06:00, 12:00, and 18:00 WIB for two minutes each cycle. Initial testing using 50 duck eggs achieved a hatching success rate of 91%. These results indicate that the developed incubator is stable, efficient, and suitable to support modern duck farming.

1. INTRODUCTION

Indonesia is one of the countries with the largest potential for duck farming in the world. This vast national duck farming asset is supported by adequate natural resources, making it a leading commodity for increasing farmers' income and welfare. Currently, various types of local meat-producing ducks have been developed in Indonesia, such as Tegal ducks, Magelang ducks, and Rambon ducks, which are known for their rapid growth and high meat quality. In addition, crossbred variants have also been developed to improve the performance of meat ducks, such as PMP ducks (Peking Mojosari Putih), hybrid ducks, and Raja ducks, which have been produced through breeding programs aimed at generating superior meat ducks. These developments have promising prospects if managed commercially and sustainably [1].

However, the development of duck farming in Indonesia is still relatively slow compared to other poultry, such as chickens and quails [2]. There is often a mismatch between market demand and the availability of duck meat for consumption or national food industry needs. According to the Central Statistics Agency (BPS) in 2023, duck meat production reached 54,000 tons, an increase of about 8.5% from the previous year. Despite the increase in production, the supply is still insufficient to meet consumer demand [3]. It is

estimated that 15–20% of national duck meat demand remains unmet. This gap is due to challenges faced by the duck farming industry, such as feed costs and climate change, which can affect productivity.

To achieve optimal productivity, duck egg incubation requires ideal environmental conditions. The required incubation temperature ranges between 37°C and 39°C, with humidity levels maintained at 60%–70% during the hatching period. Additionally, eggs need to be turned regularly, 3–4 times per day, to prevent the embryo from sticking to the shell wall. Failure to meet these parameters can result in embryo mortality or incomplete hatching. Therefore, a stable, automated, and real-time monitored incubation system is essential to create an ideal hatching environment. Several previous studies have attempted to address these issues [4].

Karsid developed an automatic egg hatching system using an Arduino Uno, a DHT22 sensor, and incandescent lamps as heat sources, along with a tray of water to maintain humidity. These components are directly controlled by the Arduino Uno. The system also includes an automatic egg turner on a scheduled rotation to ensure even heat distribution. The study achieved up to 90% hatching success; however, the system lacked Internet of Things (IoT) capabilities or remote monitoring features via smartphone applications, limiting user convenience when monitoring from a distance [5].

Another study by Yanti in developed an IoT-based duck egg incubator monitoring system using a NodeMCU ESP8266 microcontroller and a DHT22 sensor for temperature and humidity detection. The incubator could detect if the temperature reached or exceeded the set threshold of 39.3°C. When this threshold was surpassed, the system would automatically send a warning or notification to the user via a connected application. However, users were required to manually adjust the temperature, making the system less efficient due to the need for human intervention to maintain temperature stability [6].

Cahyo Ardi Prabowo's research involved the development of an IoT-based egg incubator using a PID control system and a mobile application. The PID controller was used to stabilize the temperature according to predefined conditions. The IoT system in this study utilized an ESP32 microcontroller connected to sensors via Firebase, with a user application for monitoring. The system achieved a 90% success rate. However, a limitation of this study was the DHT21 sensor's slow sampling time, exceeding two seconds, which made it less responsive for real-time monitoring of incubation conditions. For modern incubation systems that prioritize cost-efficiency, accuracy, and easy integration, the DHT21 sensor is less suitable [7].

To overcome these issues, the current study uses the DHT22 sensor, which offers higher humidity accuracy (±2% RH) and faster sampling than the DHT21 [8]. The system also includes a Real Time Clock (RTC) module to ensure precise and continuous scheduling, even during power outages [9]. Integration with the Blynk app allows both automated and manual control of the egg-turning motor, supporting smart farming practices. This research aims to design and build an IoT-based duck egg incubator using the NodeMCU ESP32 and DHT22 sensor, with an automatic turning feature and real-time monitoring through the Blynk application. The system is expected to reduce manual error, improve embryo quality, increase hatch rates, and offer a more efficient and user-friendly incubation process [10].

2. METHOD

This research is categorized as engineering research, which refers to a development method based on theoretical principles aimed at producing a product that meets specific design criteria [11]. The objective of this study is to design and develop an IoT-based duck egg incubator system equipped with an automatic turning feature to enhance hatching productivity. The research was conducted at the Electronics and Instrumentation Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, with field trials carried out at a duck farm located in Lima Puluh Kota Regency. The study period ran from February to May 2025. The data collected in this study includes time, temperature, and humidity during the incubation process [12]. The research variables consist of independent, dependent, and controlled variables. The independent variables are the incubator temperature and humidity. The dependent variable is the digital signal produced by the DHT22 sensor. Meanwhile, the controlled variables include the ESP32 microcontroller, the DHT22 sensor, and the DC motor.

The research stages include literature study, system design, prototype development, testing, and analysis. The literature study was conducted by reviewing books, journals, and previous studies related to egg incubator systems, temperature and humidity control, and the application of Internet of Things (IoT) technology [13]. The system design stage involved designing the hardware and software architecture of the incubator and determining

the main components, including the ESP32 microcontroller, DHT22 sensor, DS3231 RTC module, and the automatic egg-turning mechanism. The prototype was then developed and assembled according to the designed system [14]. Device testing was carried out to evaluate the system performance in controlling temperature and humidity and to verify the operation of the automatic egg-turning mechanism [15]. Finally, the test results were analyzed to assess system stability and the effectiveness of the incubator in supporting the duck egg incubation process [16].

The design of this research focuses on developing an egg incubator device by applying the concept of the Internet of Things (IoT). The design process is intended to estimate the initial form of the system as well as anticipate potential challenges during the development of the duck egg incubator. The design stage is divided into two parts: hardware design and software design. The purpose of the hardware design is to determine the physical structure of the incubator and the placement of sensors within the device, while the software design focuses on developing the IoT-based monitoring and control system.

The hardware design stage includes the mechanical design process, which aims to create a physical incubator structure in accordance with the predetermined specifications. The components used in building the prototype are selected based on the planned design. The component layout and configuration are illustrated in the block diagram shown in Figure 1.
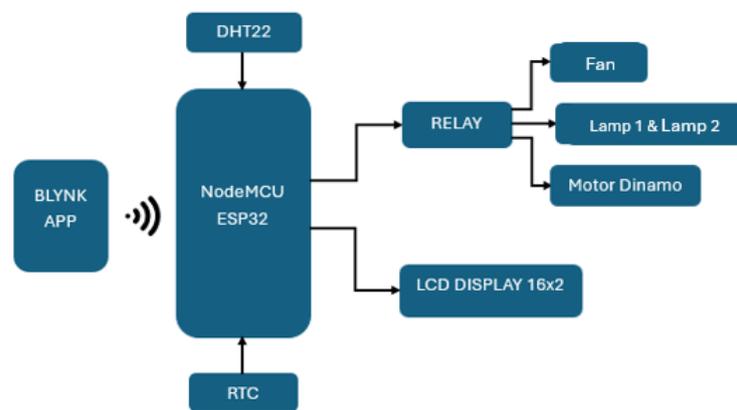

Figure 1. Control System Block Diagram

The system components were designed by arranging them according to their stages and respective functions. The components consist of the ESP32, a microcontroller integrated with Wi-Fi, which also serves as a transmitter of sensor data from the microcontroller to the internet and displays it on the Blynk application. The DHT22 temperature sensor functions as the temperature detector inside the incubator. The RTC is used for timekeeping and scheduling the motor. The servo motor acts as the egg tray actuator. The fan functions as both a cooling system and a heat distributor within the incubator. The relay module serves as a substitute for a power switch or plug. The system circuit design of the egg incubator is shown in Figure 2.
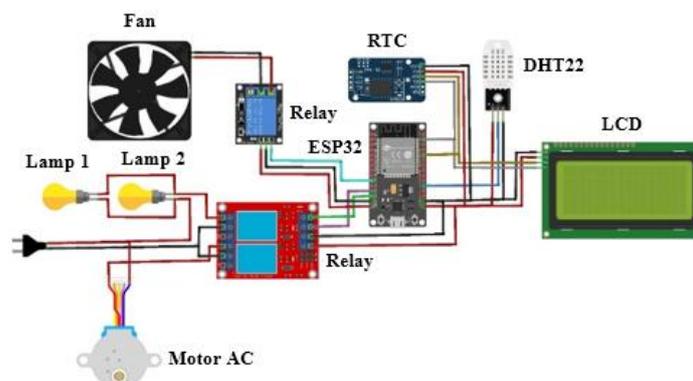

Figure 2. Tool Chain

The physical design of the duck egg incubator is constructed in the form of a box. The preassembled components are placed inside this box. The incubator box is intentionally designed to replicate the environmental

conditions required for the hatching process of duck eggs. There are five key aspects that must be considered to achieve optimal hatching results within the incubator chamber: temperature, humidity, ventilation, egg turning, and cleanliness. The design of the incubator box is shown in Figure 3.

a)

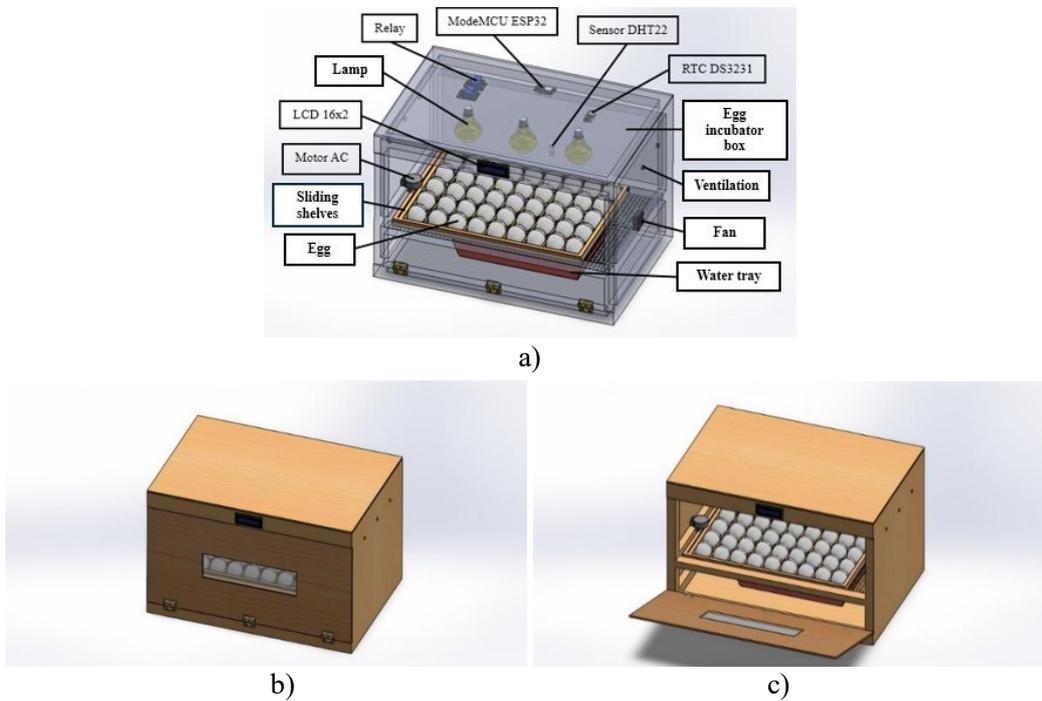b)   c)

Figure 3. a) Incubator in full view, b) Incubator in front view and c) Incubator in open condition

The software design serves as a set of instructions to support the operation of the hardware. In principle, the software functions to provide commands and execute operations on the microcontroller. The flowchart of the software used in the incubator system is shown in Figure 5.
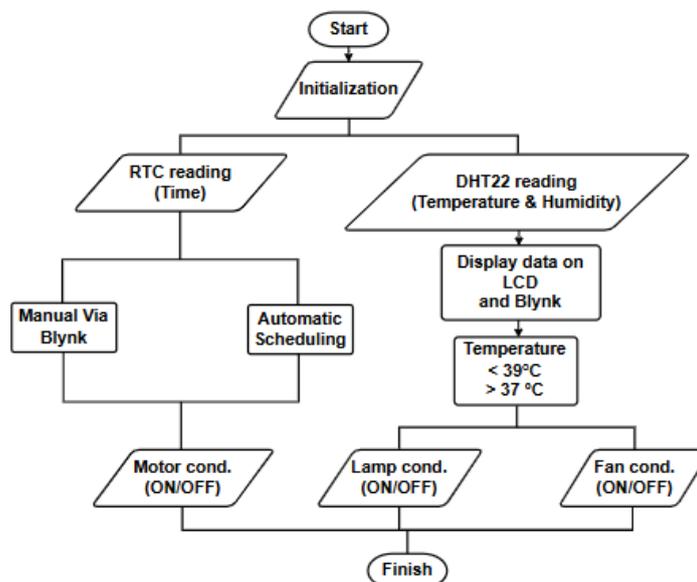

Figure 5. Tool software flowchart

The flowchart above represents software that illustrates the workflow or operation of the system using a supporting tool in this research. It begins with a start, followed by the initialization process for the pins used. Next, the system reads data from the DHT22 sensor and the RTC. The temperature and humidity readings are displayed on the LCD and the Blynk application. If the temperature is below 37°C, the lamp will turn on, while if

the temperature exceeds 39°C, the lamp will turn off. For the fan, it will turn on when the temperature exceeds 39°C and turn off when the temperature is below 37°C. The RTC reading is used for scheduling the motor, which is set to run at least three times within 24 hours, operating for 2 minutes each time.

3. RESULTS AND DISCUSSION

This study aims to determine the design specifications for developing an IoT-based duck egg incubator equipped with an automatic turning feature, as well as to evaluate the performance of the system in improving hatching productivity. The background of this research stems from the issues commonly found in manual duck egg incubation, which often fails to maintain optimal temperature and humidity stability, along with unscheduled egg turning [17]. These conditions contribute to the low hatching success rate. Therefore, the system developed in this study is expected to enhance the efficiency and effectiveness of the incubation process by implementing automatic control of temperature and humidity, scheduled egg turning, and real-time monitoring of incubator conditions through the Blynk application.

3.1 Sensor Accuracy Against Standard Measuring Devices

The accuracy of the sensor readings compared to the standard measuring instrument was obtained by placing the sensor in close proximity to the reference device. The results of the temperature and humidity testing of the DHT22 sensor compared to the standard measuring instrument are presented in Table 1 and Table 2.

Table 1. Comparison Results of Temperature on DHT22 Sensor with Thermohydrometer

DHT22 (°C)	Thermohidrometer (°C)	% KSR
34,5 °C	34,5 °C	0 %
35,1 °C	35,0 °C	0,28 %
35,6 °C	35,5 °C	0,28 %
36,2 °C	36,0 °C	0,5 %
36,6 °C	36,5 °C	0,28 %
37,1 °C	37,0 °C	0,28 %
37,5 °C	37,5 °C	0 %
38,0 °C	38,0 °C	0 %
38,5 °C	38,5 °C	0 %
39,1 °C	39,0 °C	0, 28 %
Average		0,19 %
Relative accuracy		99,81 %

Table 2. Comparison Results of Humidity on DHT22 Sensor with Thermohydrometer

DHT22 (%)	Thermohidrometer (%)	% KSR
69 %	70 %	1,42 %
68 %	69 %	1,42 %
67 %	67 %	0 %
66 %	66 %	0 %
65 %	65 %	0 %
64 %	64 %	0 %
63 %	62 %	1,42 %
62 %	61 %	1,42 %
61 %	60 %	1,42 %
60 %	59 %	1,42 %
Average		0,85 %
Relative accuracy		99,15 %

Based on the testing results of the DHT22 sensor and the Thermohygrometer for temperature and humidity measurements in Table 1 and Table 2, the relative accuracy of the temperature measurement was found to be 99.81%, while the humidity measurement accuracy was 99.15%. These high accuracy values indicate that the

DHT22 sensor has strong capabilities in detecting temperature and humidity. Therefore, this sensor is well-suited for use in this final project to monitor the required temperature. These data are an important consideration in determining the ideal temperature range for successful egg hatching.

3.2   Precision of Sensor Readings in Repeated Measurements

Sensor precision was determined by repeatedly measuring the sensor's temperature and humidity readings. In this procedure, the incubator lamp was turned on for 2 minutes, and the temperature and humidity values were recorded. Then, the lamp was turned off until the sensor reading stabilized or matched the room temperature. After that, the lamp was turned on again for 2 minutes and the readings were recorded once more. This process was repeated 10 times. The results of the temperature and humidity precision of the DHT22 sensor are presented in Table 3 and Table 4.

Table 3. Precision of DHT22 sensor temperature values

Measurement	Temperature (°C)
1	32,2 °C
2	32,2 °C
3	32,2 °C
4	32,2 °C
5	32,2 °C
6	32,2 °C
7	32,1 °C
8	32,1 °C
9	32,1 °C
10	32,1 °C
Average	32,16 °C
Precision	99,84 %

Table 4. Precision of DHT22 sensor humidity values

Measurement	Humidity (%)
1	71 %
2	70 %
3	71 %
4	71 %
5	71 %
6	71 %
7	71 %
8	70 %
9	70 %
10	70 %
Average	70,6 %
Precision	99,29 %

Based on the precision test results for temperature and humidity values measured by the DHT22 sensor, the temperature measurement precision was found to be 99.84%, while the humidity measurement precision was 99.29%. These high precision values indicate that the DHT22 sensor possesses excellent capabilities in terms of accuracy and stability. Therefore, this sensor is well-suited for various applications that require accurate and reliable temperature and humidity monitoring.

3.3   Temperature and Humidity Measurement

The purpose of this temperature and humidity measurement test is to ensure that the environmental conditions inside the incubator remain optimal throughout the egg incubation process. Temperature and humidity measurements, along with monitoring of the lamp (L) and fan (K) status, were carried out over a period of two days. The results of the test are presented in Table 5.

Table 5. Precision of DHT22 sensor humidity values

No	Date	Time (WIB)	Temp (°C)	Humidity (%)	Condition
1	28/04/2025	06:15	37,7 °C	61 %	L = off , K = on
2	28/04/2025	07:00	37,6 °C	62%	L = on , K = off
3	28/04/2025	08:03	37,4 °C	61 %	L = on , K = off
4	28/04/2025	09:01	38,1 °C	63 %	L = on , K = off
5	28/04/2025	10:06	39,0 °C	63 %	L = off , K = on
6	28/04/2025	11:02	37,2 °C	66 %	L = off , K = on
7	28/04/2025	12:14	38,1 °C	66 %	L = off , K = on
8	28/04/2025	13:15	38,8 °C	65 %	L = off , K = on
9	28/04/2025	14:19	37,4 °C	65 %	L = off , K = on
10	28/04/2025	15:03	37,6 °C	64 %	L = off , K = on
11	28/04/2025	16:05	37,1 °C	65 %	L = on , K = off
12	28/04/2025	17:04	37,0 °C	64 %	L = on , K = off
13	28/04/2025	18:03	37,3 °C	62 %	L = off , K = on
14	28/04/2025	19:02	37,8 °C	61 %	L = on , K = off
15	28/04/2025	20:06	38,0 °C	61 %	L = on , K = off
16	29/04/2025	06:17	37,2 °C	59 %	L = on , K = on
17	29/04/2025	07:00	37,6 °C	63 %	L = on , K = off
18	29/04/2025	08:00	37,0 °C	62 %	L = on , K = off
19	29/04/2025	09:05	37,4 °C	63 %	L = on , K = off
20	29/04/2025	10:18	38,2 °C	60 %	L = on , K = off
21	29/04/2025	11:21	37,6 °C	61 %	L = off , K = on
22	29/04/2025	12:00	38,9 °C	60 %	L = off , K = on
23	29/04/2025	13:05	38,8 °C	60 %	L = on , K = off
24	29/04/2025	14:04	38,9 °C	60 %	L = on , K = off
25	29/04/2025	15:03	38,5 °C	61%	L = on , K = off
26	29/04/2025	16:12	38,5 °C	62 %	L = on , K = off
27	29/04/2025	17:07	37,4 °C	62 %	L = off , K = on
28	29/04/2025	18:14	38,7 °C	61 %	L = off , K = on
29	29/04/2025	19:02	37,8 °C	61 %	L = off , K = on
30	29/04/2025	20:06	38,0 °C	61 %	L = off , K = on
	Average		37,9 °C	62,2 %	
	Standard Deviation		± 0,63°C	± 1,90%	

Monitoring was conducted daily from 06:00 to 20:00 WIB. Based on the data in Table 10, it can be seen that the temperature and humidity were maintained within the ideal range, specifically between 37°C – 39°C for temperature and 60% – 70% for humidity. The recorded data shows an average temperature of 37.9°C and an average humidity of 62.2%, indicating that the environmental conditions inside the incubator remained within the optimal range. In addition, the standard deviation for temperature was ±0.63°C and for humidity was ±1.90%. These values indicate that fluctuations in temperature and humidity during the test remained within acceptable limits for duck egg incubation. The system successfully maintained environmental stability effectively.

3.4   Development and Hatching Success

This test aims to monitor and evaluate the development of the eggs during the incubation process. By conducting this test, it is possible to assess the quality of the eggs, embryo development, and the effectiveness of the incubator. The results of the egg incubation development obtained are as follows:

$$Phatching\ percentage = \frac{number\ of\ eggs\ hatched}{total\ number\ of\ eggs} \times 100\%$$
$$= \frac{41}{45} \times 100\%$$

$$= 91\,\%$$

The purpose of this study was to determine the design specifications of an Internet of Things (IoT)-based duck egg incubator equipped with an automatic egg-turning feature and to evaluate the performance of the system in improving hatching productivity. This research was motivated by problems in manual incubation methods, which often fail to maintain stable temperature and humidity and do not provide a regular egg-turning schedule, resulting in low hatching success rates. Therefore, the system developed in this study was designed to automatically control temperature and humidity, perform scheduled egg turning, and enable remote monitoring of the incubator conditions through the Blynk application.

The testing data included the calibration results of the DHT22 sensor, temperature and humidity measurements over two days, and the hatching success rate. The results showed that the average incubator temperature was 37.9°C with a standard deviation of ±0.63°C, while the average humidity was 62.2% with a deviation of ±1.90%. The error rate of the DHT22 sensor compared to a standard measuring instrument was very low, at 0.157% for temperature and 0.182% for humidity, indicating that the sensor has high accuracy and precision. The automatic egg-turning system operated according to the scheduled times at 00:00, 06:00, 12:00, and 18:00 WIB, with a duration of two minutes in each cycle.

Compared with previous studies, the system developed in this research integrates IoT technology, temperature control, and an automatic egg-turning mechanism using a more accurate sensor. This research contributes to the development of poultry farming technology through IoT-based instrumentation and automation, which can improve work efficiency, minimize human error, and increase the hatching success rate to 91% from 50 tested duck eggs.

However, this study has several limitations because the testing was conducted in only one incubation cycle and under relatively stable environmental conditions. Therefore, future research is recommended to conduct testing across multiple incubation cycles and in various environmental conditions, as well as to develop additional features such as renewable energy integration, camera-based monitoring, and cloud-based data storage.

4. CONCLUSION

This study addressed the problem of low hatching success in manual duck egg incubation caused by unstable temperature and humidity conditions and irregular egg turning. To overcome these limitations, an Internet of Things (IoT)-based duck egg incubator equipped with an automatic turning system was designed and developed. The results show that the incubator, with dimensions of 60 × 40 × 40 cm and a capacity of approximately 50 eggs, successfully integrates key components including the ESP32 microcontroller, DHT22 sensor, RTC module, AC dynamo motor, I2C LCD, and the Blynk application for remote monitoring. The system is capable of maintaining incubation conditions within the optimal range, achieving an average temperature of 37.9°C and humidity of 62.2% with minimal fluctuations. Temperature and humidity data were consistently displayed on both the LCD and the Blynk application, while the automatic egg-turning mechanism operated accurately according to the scheduled times. The DHT22 sensor also demonstrated high measurement accuracy with very low error rates compared to standard instruments. These results indicate that the developed system is effective in providing a stable and automated incubation environment, which can improve efficiency and support modern duck farming practices. However, the testing was conducted only within a limited incubation cycle and under relatively stable environmental conditions. Therefore, future research is recommended to perform long-term testing across multiple incubation cycles and different environmental conditions, as well as to integrate additional features such as renewable energy sources, camera-based monitoring, and cloud-based data storage to further enhance system functionality.

DECLARATIONS

REFERENCES

[1]   A. Andoko dan Sartono, *Beternak Itik Pedaging*. Jakarta Selatan: PT AgroMedia Pustaka, 2013.

[2]   H. R. Rukmana, *Panduan Lengkap Ternak Itik Petelur & Pedaging Secara Intensif*. Yogyakarta: Penerbit Andi, 2014.

[3]   Badan Pusat Statistik, *Peternakan dalam Angka 2023*, vol. 8. Jakarta: Badan Pusat Statistik, 2023.

[4]   H. R. Anggorodi, *Nutrisi Aneka Ternak Unggas*. Jakarta: Gramedia Pustaka Utama, 1995.

[5]   K. Karsid, Sistem kontrol suhu dan kelembaban udara pada alat penetas telur menggunakan Arduino Uno, *Elektriese: Jurnal Sains dan Teknologi Elektro*, vol. 14, no. 1, pp. 25–32, 2024

[6]   Y. Yanti, A. Rohman, S. Maesaroh, A. Mustopa, dan R. M. Febrian, The implementation of the Internet of Things in the duck egg incubator monitoring system, *TIERS Information Technology Journal*, vol. 3, no. 2, pp. 84–90, 2022.

[7]   M. C. A. Prabowo, I. Sayekti, S. Astuti, S. T. Nursaputro, dan S. Supriyati, Development of an IoT-based egg incubator with PID control system and web application, *JOIV: International Journal on Informatics Visualization*, vol. 8, no. 1, pp. 465–472, 2024.

[8]   Y. A. Ahmad, T. S. Gunawan, H. Mansor, B. A. Hamida, A. F. Hishamudin, dan F. Arifin, On the evaluation of DHT22 temperature sensor for IoT application, in *Proceedings of the 2021 8th International Conference on Computer and Communication Engineering (ICCCE)*, pp. 131–134, 2021.

[9]   M. R. Wirajaya, S. Abdussamad, dan I. Z. Nasibu, Rancang bangun mesin penetas telur otomatis menggunakan mikrokontroler Arduino Uno, *Jambura Journal of Electrical and Electronics Engineering*, 2020.

[10] A. Faroqi, M. R. Efendi, D. T. Ismail, dan W. Darmalaksana, Design of Arduino Uno based duck egg hatching machine with sensor DHT22 and PIR sensor, in *Proceedings of the 2020 6th International Conference on Wireless and Telematics (ICWT)*, 2020.

[11] Yunaldi, *Alat Penetas Telur Ayam Otomatis Menggunakan Sensor DHT22 dan Motor Gearbox Berbasis Arduino*. Padang: Universitas Negeri Padang, 2021.

[12] M. Mahdyah, *Studi Mandiri dan Seminar Proposal Penelitian*. Tangerang Selatan: Universitas Terbuka, 2016.

[13] A. Nistico, D. Markudova, M. Trevisan, M. Meo, dan G. Carofiglio, A comparative study of RTC applications, in *Proc. 2020 IEEE Int. Symposium on Multimedia (ISM)*, pp. 1–8, 2020.

[14] F. Saputra, D. R. Suchendra, dan M. I. Sani, Implementasi sistem sensor DHT22 untuk menstabilkan suhu dan kelembapan berbasis mikrokontroler NodeMCU ESP8266 pada ruangan, *Proceeding of Applied Science*, vol. 6, no. 2, p. 1977, 2020.

[15] A. Maier, A. Sharp, dan Y. Vagapov, Comparative analysis and practical implementation of the ESP32 microcontroller module for the Internet of Things, in *Proc. 2017 Internet Technologies and Applications*

(ITA), pp. 143–148, 2017.

[16] M. Babiuch, P. Foltynek, dan P. Smutny, Using the ESP32 microcontroller for data processing, in *Proceedings of the International Carpathian Control Conference (ICCC)*, pp. 1–6, 2019.

[17] T. A. Adegbulugbe, A. O. Atere, dan O. G. Fasanmi, Development of an automatic electric egg incubator, *International Journal of Scientific & Engineering Research*, vol. 4, no. 9, pp. 914–918, 2013.