Smart fuzzy incubator for free-range chicken on internet of things

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ABSTRACT

This paper presents the design of an artificial incubator for free-range chicken eggs. The incubator is designed to maintain optimal conditions and humidity for embryo development and this incubator is equipped with an egg turning mechanism. This incubator is designed using NodeMCU 8266 hardware which is used as a control that connects to the database server, and this incubator is built using multiplex, exhaust fan, mist maker, motor tuning, DS18B20, DHT-11 and real-time clock (RTC) DS3231. The temperature and humidity conditions in the incubator are maintained within the desired range and the egg changing mechanism works effectively. The results of this research show that this artificial incubator can be a reliable and effective tool for hatching free-range chicken eggs. This incubator is very easy to use and maintain and very affordable for local free-range chicken farming. This future research will focus on determining the conditions under which the incubator will provide the best results in terms of hatching efficiency for free-range chickens.

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1. INTRODUCTION

Current technology has developed rapidly, one of these developments is the hatchery technology that has been created for egg incubators (incubators). The technology applied to incubators can imitate the behavior of chickens during the incubation period [1]. This system is designed to provide a solution to increase the number of chicks, so that it can help rebalance the ecosystem [2] and also to provide a good alternative to replace chickens in incubating eggs in their nests. This incubation is used to look after eggs which are given special treatment so that the eggs can develop into chicks [3]. An incubator is a machine that provides a good environment for the development of fertilized egg embryos, where a good artificial environment allows temperature, humidity and ventilation to be achieved in the incubation system [4]. The optimal temperature for hatching free-range chicken eggs is 37 ºC to 38 ºC [5], [6]. However, if you use an incubator, until the 19th day of the incubation period, the temperature must be maintained between 37.7 °C to 39.3 °C and humidity ranging from 50% to 65%, but after the 19th day until the chicks hatch the temperature must be reduced to 36.8 °C and humidity must be maintained at around 90% [2] and on the 21st day the incubator temperature must be increased to 37.7 °C with humidity 68% [7]. The temperature transfer from the hen to the egg is approx. 38 °C to 39 °C [8], [9]. Incubation temperature is the most influential physical factor during chicken embryogenesis because it determines embryonic and post-hatch growth, metabolism and development [10]. This incubator is designed as a substitute for natural hatching at the same time [1]. The incubator that we design specializes in free-range chickens, more precisely in incubators made for free-range chicken eggs. The egg hatching process in animal husbandry is very important [11]. To increase chick production, temperature stability in the incubator must be maintained so that the hatching process runs well. Apart from that, good temperature and humidity settings will reduce the risk of hatching failure due to changes in weather or other environmental factors. Another benefit of having this incubator is that it allows mass hatching of eggs with minimal supervision. Most incubators available on the market still use a simple ON/OFF mechanism [12] and humidity regulation is still done manually by spraying the surface of the eggs or by adding water to the water tray at the bottom of the incubator [13].

The aim of this paper is to design an incubator to regulate humidity automatically, as well as automatically control temperature settings by adjusting temperature conditions that are good for hatching free-range chicken eggs without being affected by the temperature outside the incubator. We also include a database server storage system in this incubator using internet of things technology. Where the Internet of Things is used to monitor temperature and humidity remotely anywhere via the internet [5], [14] and also connecting physical objects with sensors, software and internet connectivity for data exchange [15]. This database server will store temperature and humidity data every day until the chicken eggs hatch. Apart from that, we also designed a new and effective way of implementing rotating eggs into the incubator. The application of rotating eggs is carried out. To avoid sticking the embryo to the egg shell, the egg must be tilted 45° every 4 hours [2]. Apart from that, before the incubator was designed, we modeled it first using fuzzy Mamdani in MATLAB® software to get variable tuning of the humidity and temperature value parameters which will later be applied in this internet of things based smart incubator [8].

2. METHOD

The purpose of this chicken egg incubator is designed to control the temperature and humidity in the incubator automatically, where the farmer monitors egg incubation without having to come to the location where the incubation is located. Apart from that, the function of the internet of things is to get a fast response if the temperature and humidity in the incubator are too high, exceeding the temperature and humidity that is good for incubating free-range chicken eggs, even if the temperature and humidity are too low, it will respond quickly so that the temperature and humidity remains within a good threshold in chicken egg incubation. This automatic control of temperature and humidity with the internet of things will be stored on a database server where the data generated in the database server is in the form of temperature and humidity values every day until the chicken eggs hatch. The chronology of implementing this chicken egg incubator starts from designing the necessary components according to functional testing requirements.

2.1. Hardware

System hardware consists of fundamental blocks, where each block has an important function for its operation. On the one hand, the input is connected to a fuzzy logic block with the aim of obtaining variable tuning to obtain valid parameter values required by the user. The smart incubator also has a sensor block which has the function of collecting data for monitoring, the DHT-11 sensor has a very important feature for reading temperature and humidity; to maintain a stable temperature in the incubator it is equipped with 5 lamps, each lamp has a power of 5 watts. Meanwhile, to maintain humidity in the incubator, the DTH-11 sensor is connected to a mist maker. The Mist Maker is used as a tool that can convert water into mist to maintain humidity in the incubator, where the mist will be expelled by the exhaust fan. Apart from that, the exhaust fan functions to suck in air contaminated with pollutants such as bacteria, and unpleasant odors are thrown out of the room. Likewise, with the DS18B20 sensor, it functions to monitor the temperature and humidity in the incubator if the temperature and humidity are too high or too low due to the temperature outside the incubator. This incubator is also equipped with a turning motor which functions to rotate the eggs in the incubator, this is done to avoid sticking the embryo to the egg shell [2], where the tuning motor is connected to the real-time clock (RTC) DS3231 sensor, the RTC DS3231 sensor is used to rotate the tuning motor 4 times a day. All sensors used are connected to the NodeMCU 8266 which has a configuration to process data properly and make the best decisions according to fuzzy logic. The last block is tasked with sending warning messages via the Internet to the user, via a database server in the form of a web server.

2.2. Software

Regarding the software used, namely NodeMCU 826, where NodeMCU is a system that has a Wi-Fi feature using the 8266 chips, NodeMCU is equipped with a Micro USB port which functions for programming as well as power supply. ESP8266 is an additional Wi-Fi module for microcontrollers such as Arduino which can connect directly to Wi-Fi and form a transmission control protocol/internet protocol (TCP/IP) connection. This module has several advantages, including the voltage used is around 3.3 volts and has three Wi-Fi modes, namely station, access point and a combination of station, access point. The ESP8266 is equipped with a processor, memory and general-purpose input output (GPIO). GPIO functions to transmit data or electrical voltage, where the pins can be used as input and output distribution media, input and output can be data and electrical voltage.

2.3. System design

This chicken egg incubator equipment consists of sensors, NodeMCU and a web server platform, at the same time the device is equipped with a computer that stores data online, besides that it is equipped with data monitoring results which are displayed in the application [16] web server based in the form of a database server in real time. Another advantage of this Smart incubator is that it is equipped with a device to retrieve temperature and humidity parameter data, which comes from sensors which are then sent to the database server [16]. The database server will display the date, month, year, temperature and humidity values until the eggs in the incubator hatch. The block diagram system for the incubator is shown in Figure 1. The sensor consists of DHT-11, DS18B20 and RTC DS3231 which is used to measure temperature and humidity in the incubator.

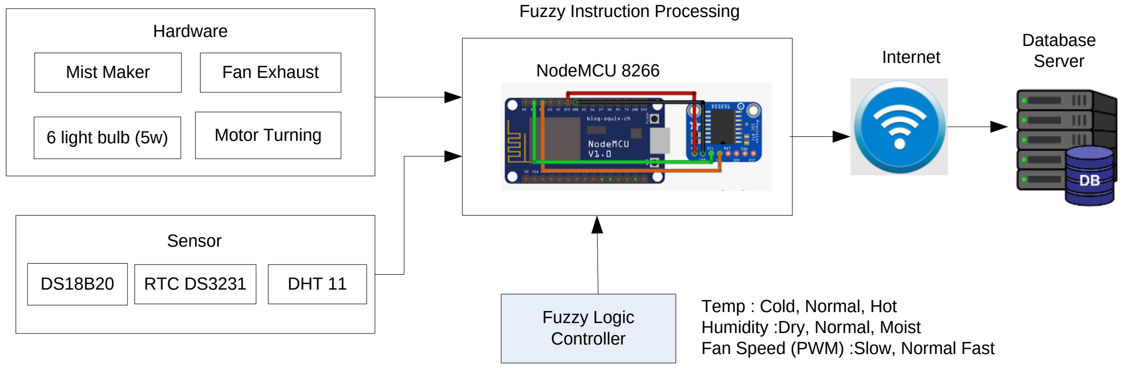


Figure 1. Flow diagram

The material for free-range chicken egg incubators is made of multiplex, with the dimensions or size designed for the incubator measuring 64×15×52 cm. In the inner part of the incubator there are several components, a rack for free-range chickens, lights, a DS3231 sensor and an egg slider motor. This part of the tool consists of three parts, the first part is for the hardware components, the second part is for the chicken eggs and the motor that drives the eggs, and the third part is the mist maker which is used to maintain humidity. The working principle of the mist maker is that a DHT-11 sensor is placed in a container containing 1 liter of water. If the temperature is high, the DHT-11 sensor functions to humidify the environment in the incubator. Figure 2. All designs of IoT-based native chicken egg incubators.

2.3.1. Fuzzy logic

To obtain better results with sensor input, fuzzy logic is used, with the aim of obtaining variable tuning values for sensor readings and improving decision making. In this project, temperature and humidity inputs are being considered for a fuzzy logic algorithm [17], The fuzzy logic component consists of fuzzification, rule base, interference engine and defuzzification [18], [19]. Regarding the temperature sensor input, it will be used to strengthen the results obtained [17], for the temperature values shown in Table 1 and the membership function in Figure 3 is defined. Meanwhile, the humidity values shown in Table 2 and the membership functions shown in Figure 4 are defined.

To get an answer to whether the temperature and humidity in the incubator are in a good condition for hatching chicken eggs, we carry out a probability process where a value greater than 127 indicates that the temperature and humidity conditions in the incubator are in a range that is not good for hatching free-range chicken eggs. The output values for a good range in hatching free-range chicken eggs are defined in Table 3. Then the membership function is shown in Figure 5. Finally on the Table 4 defines the temperature vs humidity values.

In conclusion, the NodeMCU 8266 will receive data from the DHT-11 and DS18B20 sensors, this data passes through fuzzy logic and becomes temperature and humidity data obtained from the DHT-11 sensor [17]. If the probability of the output is greater than or equal to 127, the probability that the temperature and humidity in the incubator exceed the limits, then with the DS18B20 sensor, the data obtained will be used to support the previously obtained probability. The process of changing the fuzzy data into numerical data which will be sent to the free-range chicken egg incubator. In this study, we used fuzzy logic controller (FLC) Mamdani, membership function (MF) trapezium [20], trapezoidal curve shape, the trapezoidal membership function was chosen in this study because of its efficiency and efficiency [21]. There are several forms of MF used in this fuzzy rule including triangle, Gaussian trapezoid, sigmoid, S shape and Z shape [22].

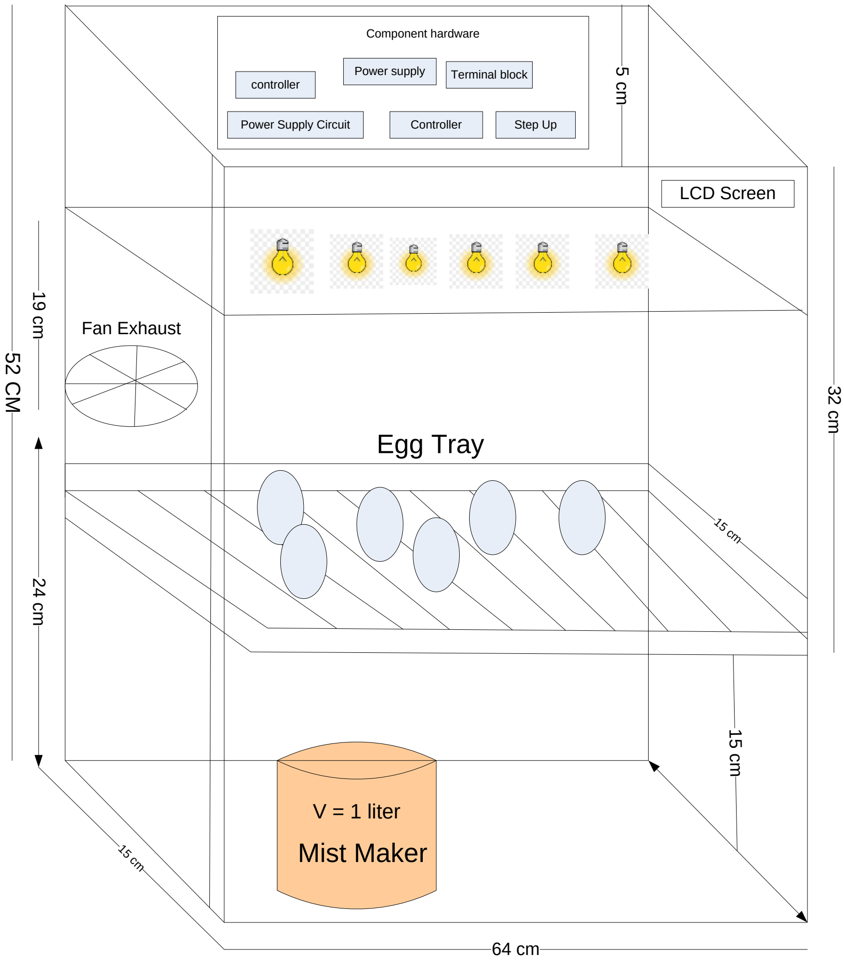


Figure 2. Incubator design

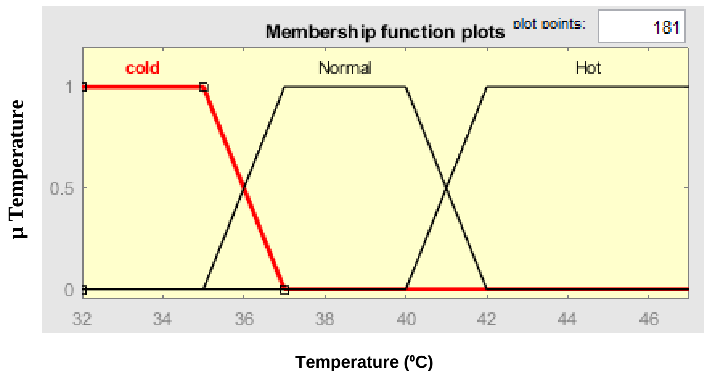


Figure 3. Temperature sensor range

Table 1. Temperature range

Level	Range
Cold	32-37
Normal	35-42
Hot	40-47

Table 2. Humidity range

Level	Range
Dry	0-33
Normal	16-66
Moist	49-100

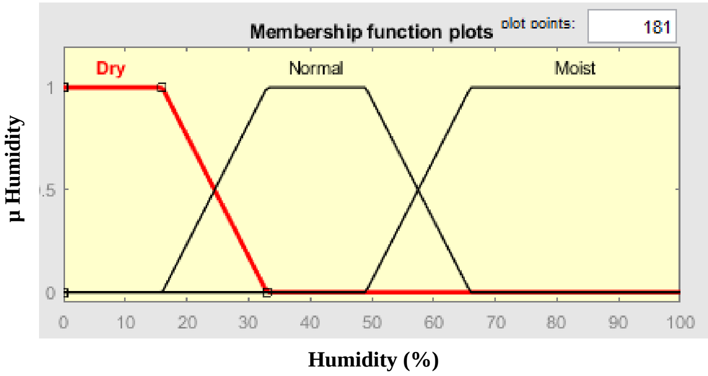


Figure 4. Humidity sensor range

Table 3. Range of output

Level	Range
Slow	0-85
Normal	42-170
Fast	127-255

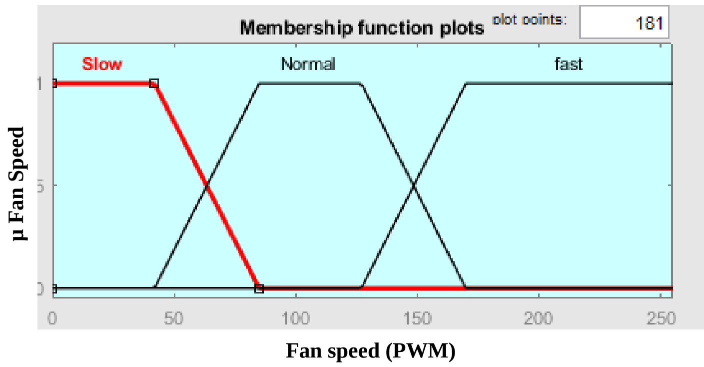


Figure 5. Range of output

Table 4. Temperature vs humidity

Humidity vs Temperature	Cold	Normal	
Dry	Slow	Slow	Fast
Normal	Slow	Slow	Fast
Moist	Slow	Slow	Fast

2.3.2. Real –time database

The physical layers used in this research are the ESP module (NodeMCU 3231) and IoT sensors (RTC DS3231, DS18B20, DHT-11), which are central elements for the interconnectivity of various components. Figure 1 depicts the spatial arrangement of the IoT-based incubation process. This IoT has additional capabilities as a server, so it can accommodate several web clients [6]. Users automatically if the temperature is outside the lower limit (37 °C) then the light will automatically turn on to control the good temperature conditions in the process of hatching chicken eggs, however if the room temperature increases to

39 °C then the fan will automatically turn on and the mist maker will emit mist as good humidity guard in the process of hatching chicken eggs. In addition, users can request to know the temperature and humidity values at this time and at any time which will be sent to the web server. The results of the data request will be displayed on a web page in PHP MyAdmin MySQL.

2.3.3. Web server application

IoT is a network of devices and physical entities equipped with sensors and actuators, where these devices can collect and send data via the internet, while devices with actuators can change entities in the physical world and communicate data via the internet like sensors [23]. The IoT system architecture used generally has four layers for interconnecting hardware and software components. four layers including physical layer (ESP module, IoT sensor, Arduino), edge layer (router, Sigfox base station), cloud services layer (firebase, Heroku, Sigfox backend) and application layer (web, mobile) [24]. In research, the IoT system architecture consists of four layers, namely: physical layer (ESP module, IoT sensor), edge layer (Sigfox base station), cloud services layer (database server) and application layer (web server). The following architecture used in this research is shown in Figure 6.

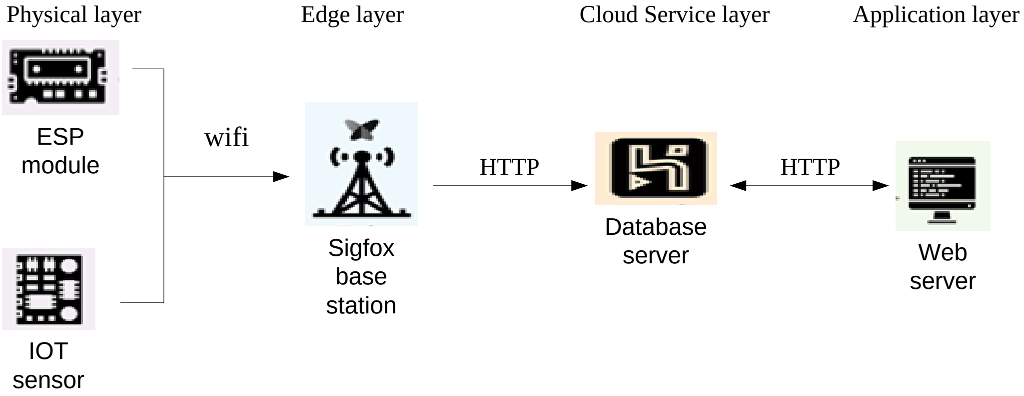


Figure 6. IoT system architecture used in free-range chicken egg incubators

3. IMPLEMENTASI

3.1. System in the incubator

Testing of the IoT-based native chicken egg incubator was carried out twice. The first experiment used four eggs and the second experiment was carried out using two chicken eggs, where the capacity of chicken eggs in the incubator was 50 chicken eggs. The incubation cycle for chicken eggs is twenty-one (21) days [6]. The hatching process for free-range chickens using a brood hen takes 21-22 days [25] and the gradual process of embryogenesis and metabolism in chicken eggs occurs at 15-21 days [26].

In the inner incubator according to Figure 7 there are several internal supporting components. Chicken egg incubator trials were carried out once for 21 days to test the performance of the egg incubator that was made. The aim of creating an automatic egg incubator that can connect to the internet and send a database to the user is to make it easier for breeders to process egg hatching, to help breeders and cultivators monitor the hatching process. After inserting the egg and having selected the mode based on the type of egg inserted, the hatching process begins. This hatchery uses chicken eggs as a testing tool to show whether this tool is successful or not. The chicken egg will rotate every day to balance the heat in the chicken egg in Figure 8.

On the twenty-first day the eggshell begins to open, and the chick's heartbeat can be seen. If you do not get help to open the chicken eggshell, the chicken will die due to lack of oxygen, therefore researchers need help in opening the chicken eggshell so that the chicken can quickly get out of the shell and not run out of oxygen if it stays in the chicken eggshell for too long. The chick is unable to break the eggshell, so if the eggshell is not broken it will result in the prospective chick dying during the hatching process. [11], therefore researchers need help to open the shell. Meanwhile, the egg breaking is done naturally by the mother using the hen's feet. The following process of hatching a chicken out of the chicken shell is shown in Figure 9. Based on Figure 9, the incubator tool has worked well, with evidence that two experiments were carried out on eggs in the incubator that were able to hatch, from the first experiment using six chicken eggs and two eggs hatching, and in the second experiment using twenty-three eggs. The following are the results of hatching free-range chicken eggs using a smart incubator, shown in Figure 10.

Figure 7. Physical product

Figure 8. Chicken eggs days 1–21

Figure 9. Chicken eggs begin to hatch on the 21st day

Figure 10. The chicken has hatched in good health

3.2. Incubator design

To start programming, we will use the digital output from the sensor used in this free-range chicken egg incubator. Digital output from the sensor, where the NodeMCU 8266 uses Wi-Fi to send temperature and humidity data to the server database, where the data is used to determine good temperature and humidity limits for hatching free-range chickens. The following will define the incubator program flow shown in Figure 11.

3.3. Database user interface

Figure 12 presents the monitoring menu on a web server-based application called Piyiq. This application is programmed with a web server using PHP MyAdmin. The main function of the Piyiq application is acquiring data from the database in real-time and then displaying it on the web server screen. Figure 12 shows real-time temperature and humidity data, starting from the first day until the day the chicken eggs hatch. This application is used to find out the ideal temperature and humidity for hatching free-range chicken eggs. Apart from that, this web server application is used to make it easier for users to monitor temperature and humidity conditions in the incubator in real-time. In the data displayed on the ever web, it is ID, temperature, humidity, date, month, and year.

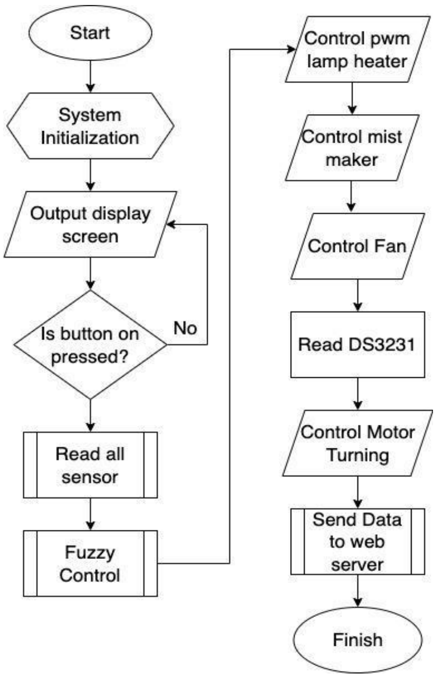
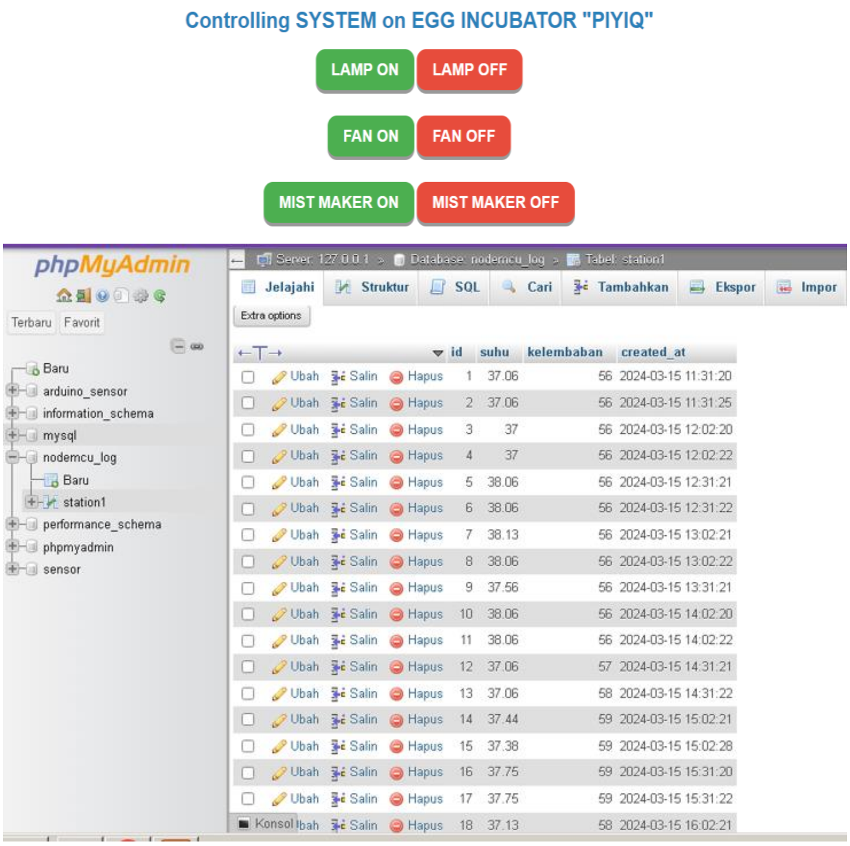


Figure 11. Workflow diagram of incubator



	id	suhu	kelembaban	created_at
Ubah Salin Hapus	1	37.06	56	2024-03-15 11:31:20
Ubah Salin Hapus	2	37.06	56	2024-03-15 11:31:25
Ubah Salin Hapus	3	37	56	2024-03-15 12:02:20
Ubah Salin Hapus	4	37	56	2024-03-15 12:02:22
Ubah Salin Hapus	5	38.06	56	2024-03-15 12:31:21
Ubah Salin Hapus	6	38.06	56	2024-03-15 12:31:22
Ubah Salin Hapus	7	38.13	56	2024-03-15 13:02:21
Ubah Salin Hapus	8	38.06	56	2024-03-15 13:02:22
Ubah Salin Hapus	9	37.56	56	2024-03-15 13:31:21
Ubah Salin Hapus	10	38.06	56	2024-03-15 14:02:20
Ubah Salin Hapus	11	38.06	56	2024-03-15 14:02:22
Ubah Salin Hapus	12	37.06	57	2024-03-15 14:31:21
Ubah Salin Hapus	13	37.06	58	2024-03-15 14:31:22
Ubah Salin Hapus	14	37.44	59	2024-03-15 15:02:21
Ubah Salin Hapus	15	37.38	59	2024-03-15 15:02:28
Ubah Salin Hapus	16	37.75	59	2024-03-15 15:31:20
Ubah Salin Hapus	17	37.75	59	2024-03-15 15:31:22
Ubah Salin Hapus	18	37.13	58	2024-03-15 16:02:21

Figure 12. Real-time display on Piyiq application

4. RESULTS AND DISCUSSION

The design of this smart incubator meets our expectations, being able to hatch free-range chicken eggs within the expected limits. We carried out two experiments in this smart chicken egg incubator, the first experiment used 6 free-range chicken eggs and the second experiment used 23 free-range chicken eggs. When comparing the two experiments, several things emerge, which we will describe shortly.

4.1. Results 1

For this section, data was obtained by carrying out tests using 6 chicken eggs, where the results are shown in Figure 12. From Figure 12 it shows that the temperature in the system shows minimal fluctuation with the lowest temperature recorded being 36 °C and the highest reaching 37.94 °C as shown in Figure 12. Which is shown in Figure 13. It can be concluded that the temperature remains unaffected by changes in humidity, the graph in Figure 13 shows that the minimum humidity level is 40 °C and the maximum is 59 °C. However, there are minimal fluctuations in the incubation phase, the humidity fluctuations that occur are caused by frequently opening the door during the hatching phase to monitor the progress and development of chicken eggs in the incubator [12].

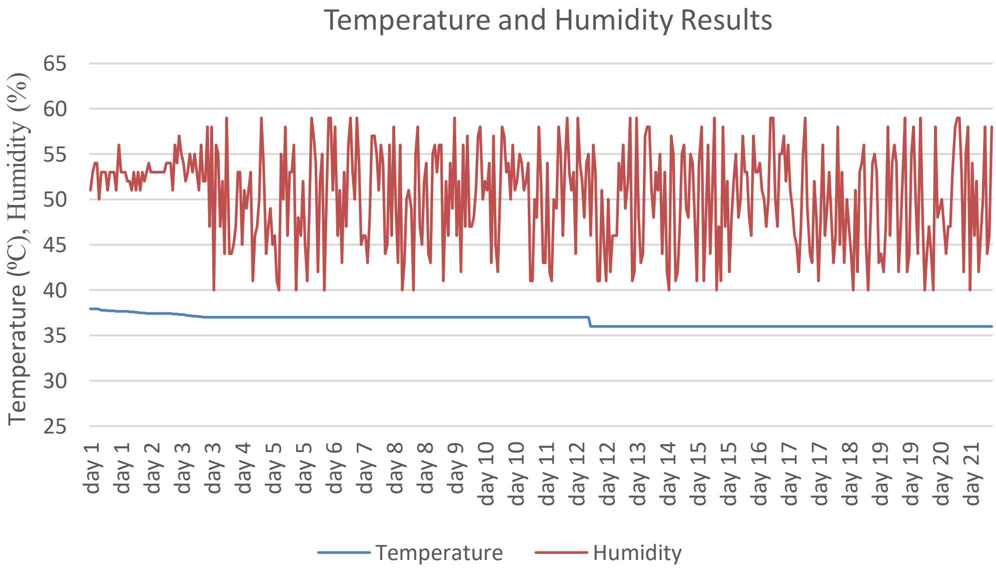


Figure 13. Temperature and humidity results

Although this study was not intended to determine the capacity of the incubator to hatch, fertilized free-range chicken eggs were incubated under various conditions only to test whether the incubator could work properly, and hatching occurred as shown in Figure 10 and the incubator components used were shown in Figure 1. The experimental results in Figure 12 show that the temperature in the incubator did not change significantly, 36 °C to 38 °C, but on day 11 and day 12 the temperature decreased, this was because changes in temperature outside the incubator had a slight effect on the stability of the temperature inside the incubator. If the incubator is placed in a place with a cooler temperature, the temperature inside the incubator will also be affected, therefore the device is equipped with several hardware that can keep the incubator temperature stable between 36 °C to 38 °C to minimize temperature changes due to the temperature around the incubator.

4.2. Results 2

In connection with this section, the data was obtained by carrying out another experiment by increasing the number of free-range chicken eggs in the incubator. The number of eggs used in the second experiment was 23 chicken eggs, where the results obtained were as in Figure 14. It can be concluded from Figure 13 that the average. The average temperature in the incubator is between 36 °C to 38 °C with a humidity value of around 40% to 59%. The number of eggs in the incubator does not affect the temperature and humidity in the incubator, the temperature and humidity in the incubator are the same when there are 6 eggs and 23 eggs in the incubator.

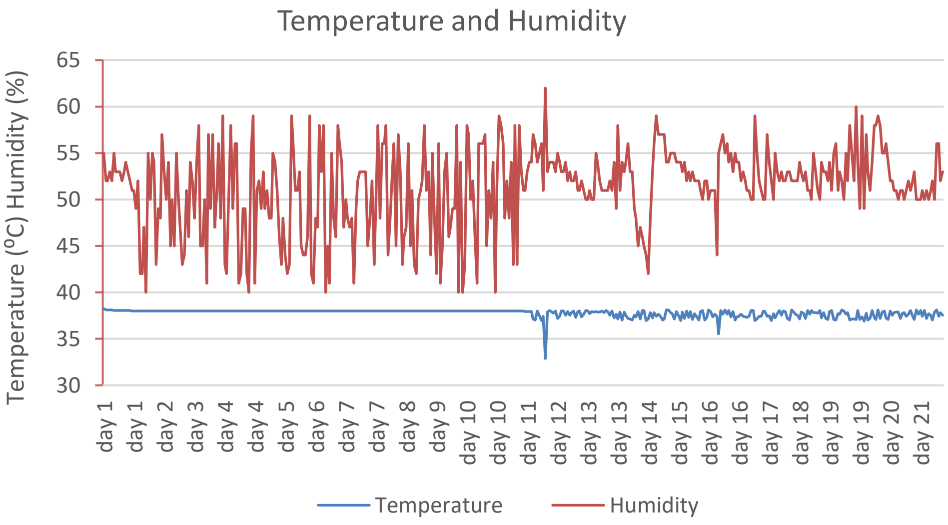


Figure 14. Temperature and humidity results

4.3. Biological performance

Biological testing is used to determine the hatchability of incubators and the percentage of egg fertility in free-range chicken eggs [9]. In research on free-range chicken eggs using a smart incubator, the eggs were turned every four hours to avoid the yolk sticking to the shell. Reduced strength and thickness of egg shells can easily cause eggs to break and eggs with thin cuticles are more susceptible to bacteria, resulting in production failure [27]. The percentage of fertility and hatchability of chickens is determined using (1) and (2).

$$\%\ Fertility = \left(\frac{Number\ of\ fertile\ eggs}{Number\ of\ eggs\ in\ the\ incubator}\right)100 \tag{1}$$

$$\%\ Hatchability = \left(\frac{Number\ of\ chicks}{Number\ of\ fertile\ eggs}\right)100 \tag{2}$$

The test results from 29 chicken eggs in the incubator, only 5 eggs were able to hatch within 21 days. In the first test six chicken eggs were used and two chicken eggs were successful in hatching, while in the second experiment 23 chicken eggs were used and those were successful in hatching. 3 chicken eggs. So based on Table 5, the average fertility percentage is 23.15, this is because the researchers did not sort fertile and infertile eggs. Where fertile eggs are eggs that contain embryos, while infertile eggs are eggs that do not contain embryos. In most hatcheries and farms, fertilized and unfertilized eggs are separated manually by human vision and traditional methods after placing the eggs in the incubator [28]. Detect fertile eggs by placing the chicken eggs in the incubator for three days. After three days the eggs are removed from the incubator and then exposed to dim, sharp light, so that the inside of the egg is visible and helps its fertility status. The characteristics of fertile eggs contain androgens [29]. Androgen is a hormone that plays a role in growth. So, if a fertile egg is seen with the naked eye using a flashlight there are embryo fibers, but if the egg is infertile there are no embryo fibers or when this is detected the egg will be light in color with no buds. Another opinion is that egg infertility is a condition that affects the reproductive system, characterized by the inability to develop the embryo [30]. Fertility and hatchability are two main parameters that greatly influence the productive performance of a chicken breed [31]. There are several egg parameters that are known to have hatchability and chicken quality such as egg weight, shape, shell characteristics and content consistency [32].

Table 5. Biological egg test results

Smart incubator	Fertility percentage	Hatchability percentage
Testing 1	33.3	100
Testing 2	13.0	100
Total	46.3	200
Average	23.15	100

5. CONCLUSION

The incubator is designed to make it easier for free-range chicken breeders to hatch, this is done so that breeders can control the age of the chicks. This smart incubator has been running well with proof that the eggs are able to hatch. This incubator is also equipped with real-time temperature and humidity control which can be accessed anywhere as long as it is connected to the internet on the database server. Apart from maintaining good temperature and humidity during hatching, determining fertile eggs is also important to determine whether the smart incubator is performing well and vice versa. This incubator tool can be used by farmers on a small or large scale.

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