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Implementation of the Fuzzy Logic Mamdani Method in the KUB Chicken Egg Incubator

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***Abstract*— Poultry farming plays an important role in rural Indonesia's economy, with increasing demand for poultry meat and protein-rich eggs. One of the main challenges for farmers is the limited production of chicken seeds and suboptimal egg incubation methods. Modern egg incubators offer a solution with higher ease and efficiency compared to traditional methods. However, existing machines on the market have weaknesses, such as less accurate temperature and humidity control, and less optimal power source switching. The use of fuzzy logic methods in egg incubators has proven to be more efficient than manual methods, with a hatching success rate of 100% for 10 eggs. Fuzzy logic-based egg incubators start hatching earlier and more on days 18 and 19, while manual methods begin on days 19 and 20. The automatic egg-turning process in fuzzy logic machines saves labor and reduces the risk of error. This research highlights the importance of using accurate sensors and optimal temperature and humidity control systems to improve the success rate of chicken egg hatching.**

***Index Terms*— egg hatching; fuzzy logic; humidity; poultry farming; temperature.**

I. Introduction

The livestock business is a business that is quite popular in society, especially poultry farming. Poultry farming is one of the driving forces for economic development in Indonesia, especially in rural areas. Not only that, very rapid population growth will also have an impact on increasing food, especially the need for poultry meat or eggs which are rich sources of protein. This needs to be balanced with an adequate supply of food, so that the need for food that has a large source of protein remains met[1].

The main problem experienced by farmers is the limited production of chicken seeds so they are unable to serve all the buyers who order[2]. One aspect of the cause is that hatching of eggs is not optimal. The demand for poultry is increasing quite significantly every month, one of which is the proliferation of food stalls and restaurants that provide menus made from poultry. To meet this demand, breeders will not have enough time if they only rely on traditional methods because they cannot mass produce them, therefore technology is needed that can improve and make it easier to hatch eggs, namely egg incubators[3].

Hatching eggs using an egg incubator has many advantages and conveniences compared to traditional methods[4]. One of them is that eggs can be hatched in large quantities, but apart from that, certain intensity and precision is required in hatching eggs using an incubator, starting from selecting eggs, egg storage methods (position or location of eggs), temperature and humidity which we must pay attention to.

Currently, egg incubator machines have been widely discussed in previous research and are also widely sold on the market, but the automatic egg incubator machines on the market are less efficient to use because the light bulb that functions as a room heater is only controlled to turn on and off. This often causes the bulb to quickly become damaged (no longer functioning), and a non-functioning bulb will affect the success of the hatching process. For this reason, there is a need for a more efficient and smart egg incubator.

The problem that is often faced in the process of hatching chicken eggs is that the temperature and humidity in the incubator must be in accordance with the needs of the hatching eggs, so a temperature and humidity control system is needed that can be adjusted to the needs of the hatching eggs. There are five main things that need to be paid attention to in the egg hatching room, namely temperature, humidity, ventilation, turning the eggs and cleanliness of the hatching room [5]. According to the Banten Agricultural Technology Research Center (BPTP), the incubation temperature occurs at 38ºC to 39.5ºC and air humidity is around 60% RH to 70% RH [6]. The incubation temperature is between 36ºC – 42ºC with air humidity of 55% - 60% RH[7]. Embryos will develop if the air temperature around the egg is at least 21.11ºC and the best temperature is between 38ºC-40ºC[8].

Research on egg incubators was carried out by [9] using an LM35 temperature sensor and a heating element in the form of a 5W/220VAC light bulb. The result is that the temperature generated by the heating element in the egg incubator room can be measured and controlled by a temperature sensor from 37.5ºC to 39ºC. The drawback of this research is that the humidity factor was not involved and temperature control was still manual by pressing a push button.

Other research on egg hatching machines has also been carried out by [10]using a DHT11 sensor which functions to measure temperature and humidity and a heating element in the form of a 5W/220VAC incandescent lamp. The temperature generated by the heating element is 37ºC to 40ºC and the stepper motor functions as a machine for turning the eggs back and forth automatically. The shortcomings of this research are that when the lights go out the egg incubator does not function and there is no tool that can even out the air temperature in the egg incubator.

Furthermore, research conducted by[11] measured temperature and humidity combined with fuzzy logic using DHT11. The object used was free-range chicken eggs, and the success percentage reached 88.89%, but the drawback was that when the electricity went out, the egg incubator could not function.

Based on previous research, there are still several shortcomings, therefore this research makes an egg incubator using the Mamdani fuzzy logic method. The research chooses the fuzzy logic and Mamdani method for the KUB chicken egg incubator due to their ability to handle the non-linear and complex interactions of temperature and humidity control. Fuzzy logic effectively manages uncertainty and imprecise data, while Mamdani rules are intuitive and resemble human decision-making, making them easy to implement and understand. This method provides precise, adaptive control essential for maintaining optimal conditions in the incubator, enhancing reliability and efficiency compared to conventional control methods, ultimately improving hatching success rates and egg quality.

The components used are Arduino Nano light bulb, DHT11 sensor, DS18B20 sensor 5W/220VAC light, 12V adapter, 16 x 2 I2C LCD, ACCU, 9VDC fan, AC dimmer module, 220VAC relay, push button, dynamo motor and 500W inverter. The DS18B20 sensor is used to measure temperature, while the DHT11 sensor is used to measure humidity which will be processed by fuzzy logic using the Mamdani method. The light bulb is used as a heater in this incubator, while the fan is used to regulate the humidity of the incubator.

This research uses the Mamdani method of fuzzy logic to regulate the temperature and humidity of the egg incubator so that it matches the ideal temperature and humidity. The ideal incubation temperature is between 36ºC – 39ºC and air humidity of around 60% RH - 70% RH. One of the advantages of the tool made is that when the power goes out the egg incubator will continue to operate by utilizing an Uninterruptible Power Supply (UPS).

II. METHODOLOGY

The method used in this research is experimental research which will produce a prototype of an egg incubator machine used to incubate Balitbangtan superior village chicken (KUB) eggs.

CFD simulation is used to analyze the total force and pressure difference between horizontal dive, vertical dive, and diagonal dive. The CFD simulation were run on 1:1 scale, 3-Dimension ROV model as shown in Figure 1 and main dimensions of mini-ROV model shown in Table 1.

A. *Research Design*

This research aims to design and make an egg incubator using fuzzy logic, so it requires several stages, the research flow stages carried out can be seen in Figure 1.

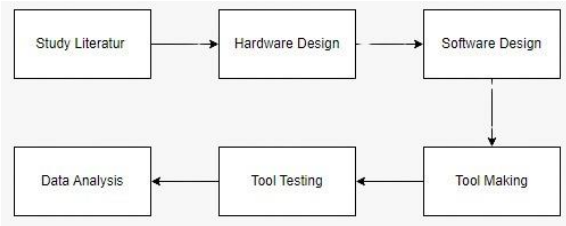

Fig. 1. Research flow diagram

The first stage is determining the title and accompanied by a search for a problem formulation related to the problem to be researched. After that, carry out tool design by preparing tools and materials, designing a series of tools. The next stage is designing the software, by creating a fuzzy logic design in Matlab. The next stage is testing the tool by testing the tool that has been made and the final step is analyzing the data.

B. *Block Diagram*

The block diagram of this research consists of 3 parts, input, process and output, as shown in Figure 2. Meanwhile, Figure 3 shows the control block diagram.

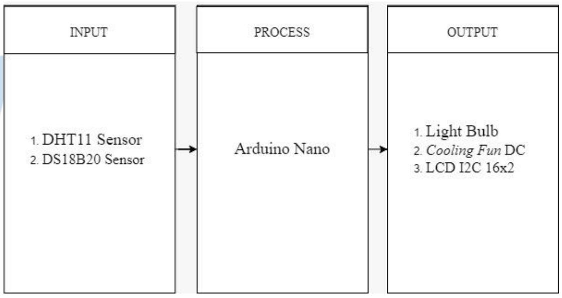

Fig. 2. The block diagram

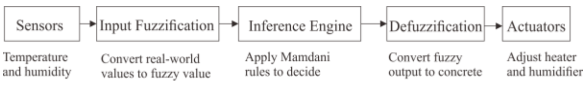

Fig. 3. The control block diagram

In the input section there is a DHT11 sensor and a DS18B20 sensor. The DHT11 (Humidity & Temperature Sensor) sensor functions to measure temperature and humidity. However, in this research, the DHT11 sensor was only used to measure humidity in the egg incubator room. Meanwhile, the DS18B20 temperature sensor (Temperature Sensor) functions to measure the temperature value in the egg incubator room. The Arduino Nano functions as a manager for the values read by the sensor and functions as a processor for each value read from the input which will then be displayed on the LCD. In the output section there are lights, fans and a 16x2 I2C LCD. The lamp acts as a heater to warm the room inside the egg incubator. The heater will dim the light automatically if the heat in the engine room exceeds the specified limit. The I2C 16x2 LCD functions to display temperature and humidity data on the egg incubator. Meanwhile, the Cooling Fun DC fan functions to even out the temperature and control humidity in the egg incubator.

C. *Circuit Design*

The circuit design of tool plays an important role in conducting research on the creation of a fuzzy logic egg incubator using the Mamdani method. The circuit design is made to make work easier when designing and making tools. To become a tool, a schematic and footprint are needed to make the PCB, then when the PCB has been made, each component is placed on the PCB board according to the schematic. Each component has been placed on the PCB so that it is connected to each other. The schematic of the egg incubator machine circuit is shown in Figure 4.

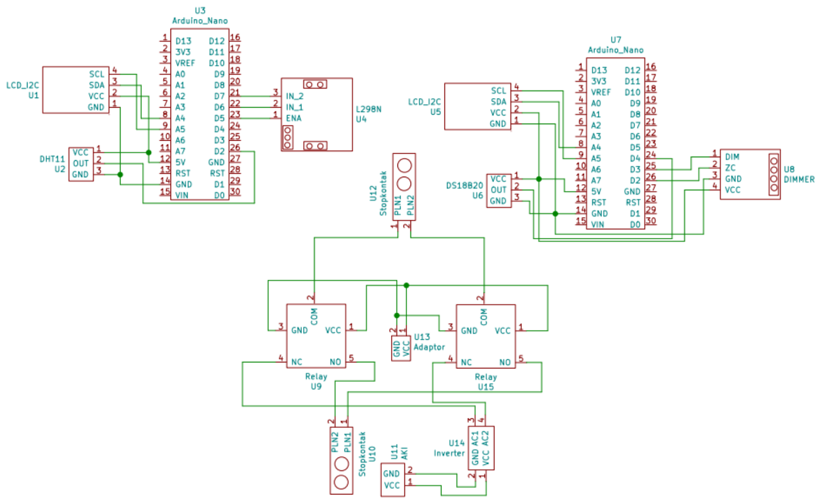

Fig. 4. The control block diagram

This incubator uses an additional UPS voltage source so that when a power outage occurs the incubator continues to function.

D. *Fuzzy Logic Design*

This research uses the Mamdani method by utilizing the MAX-MIN operation [12]. The advantage of fuzzy logic is that it can tolerate vague or inaccurate data and generally fuzzy logic is used to take an action or decision in a system [13]. Meanwhile, the advantage of the Mamdani method in fuzzy logic is that it is intuitive, covers a wide field because it uses COA (centroid of area) [14][15].

The term fuzzy is defined as a condition that is between right or wrong and is based on the degree of membership which ranges from zero to one [16]. Apart from that, fuzzy logic is also considered as an appropriate way to map input space to output space. The input space and output space in fuzzy can be linguistic variables as a substitute for using numerical calculations [17].

In this study there are two input variables, namely temperature and humidity, while the output variables in this study are light intensity and fan rotation speed. The stages in the fuzzy process include the fuzzification process, inference based on a knowledge base, and defuzzification. The inference system used in this research is the Mamdani method.

In the fuzzification stage, the fuzzy input variable consists of two membership functions, namely temperature and humidity, while the output is in the form of pulse width modulation (PWM) from the heater (light bulb) and fan. PWM settings are a way to manipulate the pulse width of a square wave with constant frequency and amplitude[18]. The temperature input memberships used are cold, warm and hot, while the humidity input memberships used are dry, humid and wet. The lights' PWM output membership includes ideal dim, bright, while the fan's PWM output membership includes slow, normal, fast.

1. Input membership function

The temperature input data is in the form of a firm value (crips) between 20 and 50. This value is obtained from the three categories of temperature values that will be used, namely temperature in the cold category when the temperature is less than 36ºC, temperature in the warm category when the temperature is between 36ºC to 40ºC, and the temperature is categorized as hot when the temperature conditions are above 40ºC. The membership degree $\mu(x)$ of temperature is expressed by equations (1), (2), and (3). Figure 5 shows a graph of the input membership function on temperature.

$$\mu_{Cold}(x) = \begin{cases} 0, & x \geq 36 \\ \dfrac{36 - x}{36 - 30}, & 30 \leq x \leq 36 \\ 1, & x \leq 30 \end{cases} \quad (1)$$

$$\mu_{Warm}(x) = \begin{cases} 0, & x \leq 30 \ or \ x \geq 45 \\ \dfrac{x - 30}{36 - 30}, & 30 \leq x \leq 36 \\ 1, & 36 \leq x \leq 40 \\ \dfrac{45 - x}{45 - 40}, & 40 \leq x \leq 45 \end{cases} \quad (2)$$

$$\mu_{Hot}(x) = \begin{cases} 0, & x \leq 40 \\ \dfrac{x - 40}{45 - 40}, & 40 \leq x \leq 45 \\ 1, & x \geq 45 \end{cases} \quad (3)$$

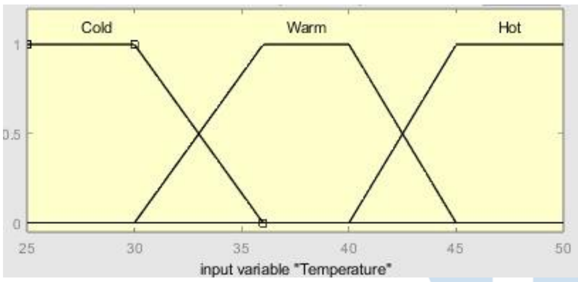

Fig. 5. Graph of input membership function on temperature

Humidity input data is also in the form of crisp values between 25 and 95. These values are obtained from the three categories of humidity values that will be used, namely humidity in the dry category when the humidity is less than 55% RH, humidity in the damp category when the room humidity is between 55 % RH 65% RH and humidity in the wet category when room humidity conditions are above 65% RH. The membership degree of humidity is expressed by equations (4), (5), and (6). Figure 6 shows a graph of the input membership function on humidity.

$$\mu_{Dry}(x) = \begin{cases} 0, & x \geq 55 \\ \dfrac{55 - x}{55 - 40}, & 40 \leq x \leq 55 \\ 1, & x \leq 40 \end{cases} \quad (4)$$

$$\mu_{Damp}(x) = \begin{cases} 0, & x \leq 40 \ or \ x \geq 80 \\ \dfrac{x - 40}{55 - 40}, & 40 \leq x \leq 55 \\ 1, & 55 \leq x \leq 65 \\ \dfrac{80 - x}{80 - 65}, & 65 \leq x \leq 80 \end{cases} \quad (5)$$

$$\mu_{Wet}(x) = \begin{cases} 0, & x \leq 65 \\ \dfrac{x - 65}{80 - 65}, & 65 \leq x \leq 80 \\ 1, & x \geq 80 \end{cases} \quad (6)$$

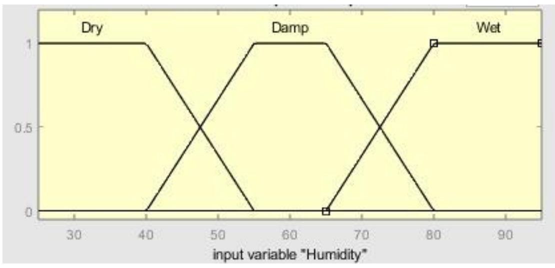

Fig. 6. Graph of input membership function on humidity

2. Output membership function

The temperature PWM output is 8bit or between 0 to 255. This value is obtained from the PWM which is sent to the microcontroller to regulate the light intensity from 0 to 255 and is converted into a fuzzy set in the form of dim, ideal, bright. The membership degree of light intensity is expressed by equations (7), (8), and (9). Figure 7 shows a graph of the light intensity output membership function.

$$\mu_{Dim}(x) = \begin{cases} 0, & x \geq 128 \\ \dfrac{128 - x}{128 - 64}, & 64 \leq x \leq 128 \\ 1, & x \leq 64 \end{cases} \quad (7)$$

$$\mu_{Ideal}(x) = \begin{cases} 0, & x \leq 64 \ or \ x \geq 192 \\ \dfrac{x - 64}{128 - 64}, & 64 \leq x \leq 128 \\ \dfrac{192 - x}{192 - 128}, & 128 \leq x \leq 192 \end{cases} \quad (8)$$

$$\mu_{Bright}(x) = \begin{cases} 0, & x \leq 128 \\ \dfrac{x - 128}{192 - 128}, & 128 \leq x \leq 192 \\ 1, & x \geq 192 \end{cases} \quad (9)$$

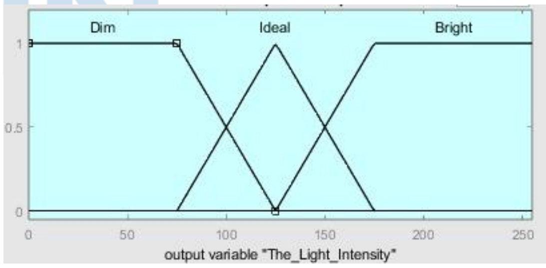

Fig. 7. Graph of output membership function at temperature

The humidity PWM output is 8bit or between 0 to 255[18]. This value is obtained from the PWM which is sent to the microcontroller to regulate the light intensity from 0 to 255 and is converted into a fuzzy set in the form of slow, normal and fast. The membership degree of fan speed is expressed by equations (10), (11), and (12). Figure 8 shows a graph of the output membership function in the form of fan speed.

$$\mu_{Slow}(x) = \begin{cases} 0, & x \geq 128 \\ \dfrac{128 - x}{128 - 64}, & 64 \leq x \leq 128 \\ 1, & x \leq 64 \end{cases} \quad (10)$$

$$\mu_{Normal}(x) = \begin{cases} 0, & x \leq 64 \text{ or } x \geq 192 \\ \dfrac{x - 64}{128 - 64}, & 64 \leq x \leq 128 \\ \dfrac{192 - x}{192 - 128}, & 128 \leq x \leq 192 \end{cases} \quad (11)$$

$$\mu_{Fast}(x) = \begin{cases} 0, & x \leq 128 \\ \dfrac{x - 128}{192 - 128}, & 128 \leq x \leq 192 \\ 1, & x \geq 192 \end{cases} \quad (12)$$

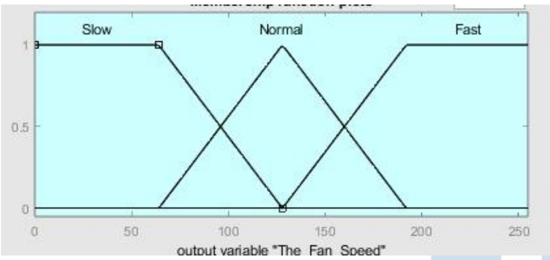

Fig. 8. Graph of output membership function on humidity

3. The rule base of fuzzy logic

After create linguistic variables, defining linguistic terms, and creating membership functions, the last step of fuzzy system design is creating a rule base. Rules describe, in words, the relationships between input and output linguistic variables based on their linguistic terms. A rule base is the set of rules for a fuzzy system. To create a rule, you must specify the antecedents, or IF portions, and consequents, or THEN portions, of the rule. Table I shows the fuzzy logic rule base used in the incubator created in this research.

TABLE I. RULE BASE

Lamp/Fan	Cold	Warm	Hot
Dry	Bright/ Fast	Ideal/ Fast	Dim/ Fast
Medium	Bright/ Normal	Ideal/ Normal	Dim/ Normal
Moist	Bright/ Slow	Ideal/ Slow	Dim/ Slow

E. Tool Working System

The working system of the egg incubator machine can be seen in the flowchart image. The following Figure 9 is a flowchart of the temperature and humidity system.

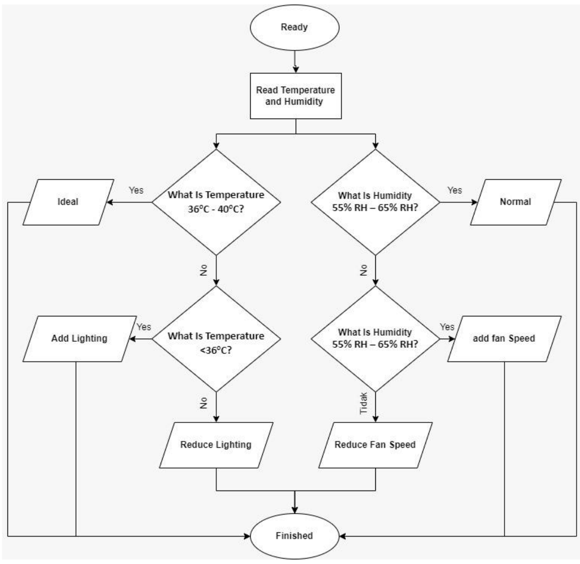

Fig. 9. Temperature and humidity system flowchart graph

The way this egg incubator works is that when the DHT11 sensor detects a room temperature of more than 40°C, the incandescent lamp will dim the lighting. If the temperature is below 36°C then the incandescent lamp will provide lighting and if the temperature is between 36-40°C then the lamp will be in ideal condition [19]. Likewise with the humidity in the egg incubator room, the ideal humidity for incubating chicken eggs is 55-65%RH [20]. To regulate the humidity in the egg incubator room, this research uses a DC cooling fan which will be controlled by fuzzy logic and the way it works is that if the DHT 11 sensor receives humidity above 65%RH, the fan will reduce the speed and if the humidity in the room is less than 55%RH then the fan will increase speed and if the humidity is between 55-65%RH then the fan speed will be normal.

To turn the egg, this research used a TYD 49-R motor dynamo. The TYD 49-R motor dynamo is controlled using a DH48S-S Timmer which will reverse the speed 4 times every day [21].

III. RESULT AND ANALYSIS

The results of this research include the results of testing the accuracy of the temperature and humidity values of the tool that has been made, testing automatic voltage transfer when a power outage occurs, testing the entire egg incubator system and discussion of hatching results.

A. Temperature and Humidity Value Testing

Accurate levels of temperature and humidity play an important role in the success of hatching eggs. In this case, it is necessary to compare the sensor from the tool that has been made with the tool that has been calibrated to determine the level of accuracy of the tool that has been made. The results of the comparison of temperature and humidity are shown in Figure 10 and Figure 10 respectively.

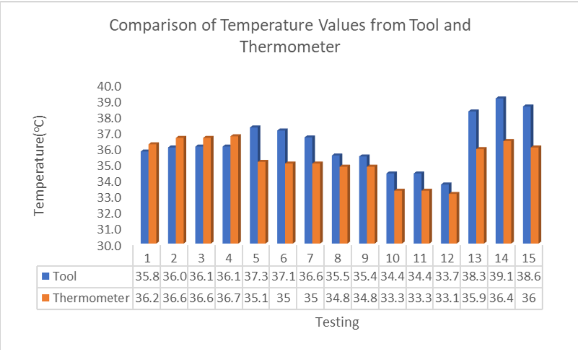

Fig. 10. The result of comparison of temperature values from tool and thermometer

Figure 10 shows the results of comparing temperature values between the tool that has been made and a calibrated thermometer. In the last three tests the difference was quite large, namely 2.4°C, 2.7°C, and 2.6°C. This is due, in part, to the sensitivity of the DS18B20 temperature sensor used in the tool. Based on the datasheet from DS18B20, the error value reaches ± 2°C.

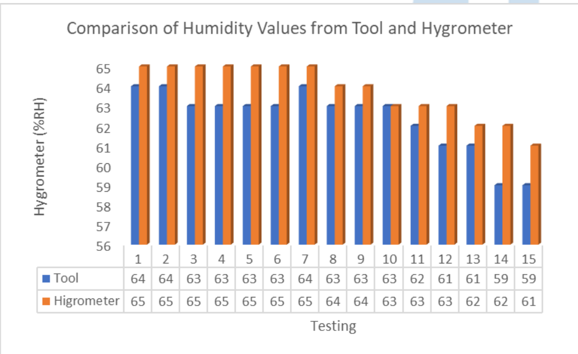

Fig. 11. The result of comparison of hygrometer values from tool and hygrometer

Figure 11 shows the results of the humidity comparison between the tool that has been made and a calibrated hygrometer. The 14th test showed the largest difference value, namely 3%RH, while the other tests only had a difference of 1-2%RH with the hygrometer. Based on the datasheet, the DHT11 humidity sensor has an error of 5% RH, so the measurement error produced by the tool is still within the error range of the DHT11 sensor. Figure 11 shows the results of comparing temperature with a thermometer and figure 12 shows the results of comparing humidity with a calibrated hygrometer.

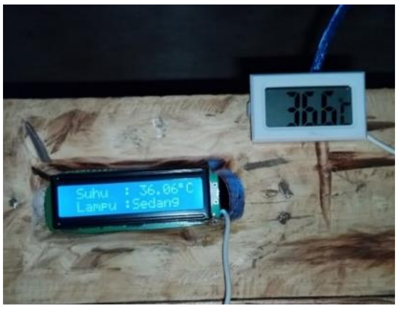

Fig. 12. Comparison results of temperature sensors with thermometer

Fig. 13. Comparison results of humidity sensors with hygrometer

B. *Comparison of PWM Value Results*

The PWM value is the result of fuzzy logic inference which describes the light intensity of the lamp and fan speed. Figure 14 and Figure 15 shows a comparison graph between the PWM values on the tool and MATLAB.

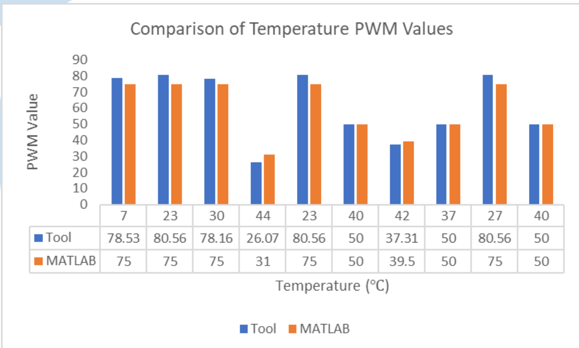

Fig. 14. Temperature PWM values comparison graph

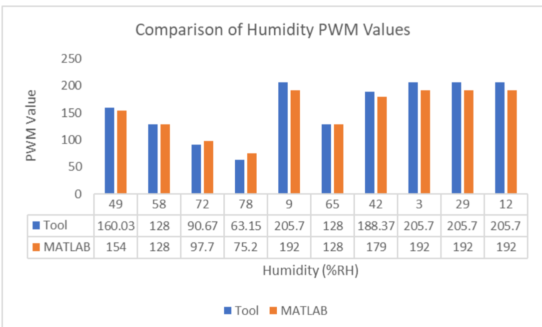

Fig. 15. Humidity PWM values comparison graph

Based on Figure 14 and 15, it can be seen that the results of comparing the PWM value of light intensity between the tool and MATLAB have the largest difference of 5.56, while the PWM of fan speed has the largest difference of 13.7.

C. *Whole System Testing*

Hatching eggs using the fuzzy logic method is in principle conditioned like a chicken egg being incubated by its mother. Hatching of chicken eggs takes approximately 21 days with the ideal room temperature of 36ºC-40ºC and ideal humidity of 55%RH-65%RH. This research carried out a test for hatching KUB chicken eggs using the Mamdani fuzzy logic method and using conventional methods as a comparison material for the tests carried out, each of the two methods hatched 10 KUB chicken eggs [22]. Testing of egg incubators using the Mamdani fuzzy logic method started hatching on 22 January 2024 and manual egg incubators starting on 30 January 2024. The egg rotation was carried out in different ways, for the fuzzy logic egg incubator machine it used a motor dynamo as an automatic tool for turning. turning the eggs, while manual egg incubators are done with human assistance [23]. The egg rotation time for both eggs is carried out 4 times a day with the hatching results per day shown in Figure 16.

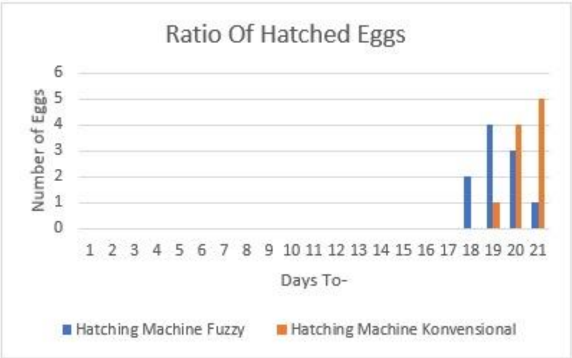

Fig. 16. PWM value comparison graph

Based on Figure 14, it can be seen that the results of the comparison between egg incubators using the fuzzy logic method and manual egg incubators, both have a percentage of 100% hatchability for 10 eggs each, however hatchability using the fuzzy logic method is better than when using manual methods. Where the testing of eggs hatched using the fuzzy logic method started to hatch on the 18th day and more hatched on the 19th day, while eggs hatched using the manual method started to hatch on the 19th day and more hatched on the 20th day. Turning the eggs in the fuzzy logic incubator is done automatically so that it can save energy and avoid forgetting to turn the eggs. The egg hatching process can be seen in Figure 17 and Figure 18.

Fig. 17. Egg hatching results using fuzzy logic

Fig. 18. Hatching eggs using conventional methods

D. *Automatic Electrical Voltage Transfer Testing*

Electrical voltage is one of the important things for running an egg incubator. In general, egg incubator machines are run from a PLN voltage source. To anticipate problems with the PLN voltage source, this research implemented a voltage source shift. The voltage transfer is carried out automatically by relying on a relay which will regulate the transfer of the voltage source when the PLN electricity source goes out. In this research, an Uninterruptible Power Supply (UPS) is used as a backup voltage source. The UPS used has a power rating of 360VA, power consumption of 360W, output voltage of 230V and input and output frequencies of 50/60 Hz. The test was carried out by connecting the UPS and the PLN voltage source to the relay, then connecting the relay to the egg incubator. Figure 19 shows a device that gets voltage from the UPS.

Fig. 19. UPS is used in incubator

The test of switching the voltage source from PLN to the UPS of the egg incubator machine was successfully carried out, but with a full battery condition, the UPS could only replace the PLN function for less than 1 hour with a stable voltage output of 220 volts. Figure 18 shows the voltage source transfer test from PLN to UPS.

IV. Conclusion

Based on the research that has been carried out, it can be concluded that temperature and humidity settings using a fuzzy logic system are able to maintain temperature and humidity in accordance with the given set points, namely 36 – 40°C and 55–65%RH. In this research, calibration results were obtained from testing the DS18B20 sensor and the DHT11 sensor with a hygro-thermostat which had a difference in values of 0.5 – 2.7°C and 1-3% RH. Egg hatching testing using fuzzy logic has a success rate of 100% for the 10 eggs hatched, each of the two methods hatches 10 eggs. Where the results of the hatching test on the egg incubator machine used fuzzy logic by rotating the egg rack 4 times a day and managed to hatch early, precisely on the 18th to the 20th day, while the results of the hatching test on the manual egg incubator machine by rotating the egg rack 4 times a day has a percentage of egg hatching success rate of 100% and they start to hatch on the 19th to the 21st day. In this research, the application of the voltage source switching system from PLN to UPS was successful but only lasted less than 1 hour. This can be concluded that the use of UPS is not yet efficient when applied to egg incubators.

References

[1] H. Hafid, A. Indi, D. Sutopo, D. M. Daoed, A. Pratiwi, and L. Sahaba, "BIMBINGAN TEKNIS BUDIDAYA AYAM KAMPUNG SUPER UNTUK PEMBERDAYAAN POTENSI MASYARAKAT DI KELURAHAN MATABUBU KECAMATAN POASIA KOTA KENDARI," *Anoa J. Pengabdi. Masy. Sos. Polit. Budaya, Hukum, Ekon.*, vol. 2, no. 3, 2021, doi: 10.52423/anoa.v2i3.22550.

[2] R. Rozalina, B. R. Juanda, K. M. Z. Basriwijaya, and L. A. Krista, "Pemberdayaan Kelompok Wanita Tani Melalui Keterampilan Beternak Ayam Ras Petelur di Desa Bate Puteh Kecamaatan Langsa Lama Kota Langsa," *J. Masy. Madani Indones.*, vol. 2, no. 4, 2023, doi: 10.59025/js.v2i4.165.

[3] Z. Alfath, F. Basuki, and R. A. Nugroho, "PENGARUH TINGKAT KEPADATAN TELUR YANG BERBEDA TERHADAP EMBRIOGENESIS, LAMA WAKTU PENETASAN DAN DERAJAT PENETASAN TELUR IKAN TAWES (Barbonymus gonionotus)," *Sains Akuakultur Trop.*, vol. 4, no. 2, 2020, doi: 10.14710/sat.v4i2.4643.

[4] R. P. Dewi and W. Arnandi, "Peningkatan Produktivitas Peternak Itik Melalui Penerapan Mesin Penetas Telur," *JPPM (Jurnal Pengabdi. dan Pemberdaya. Masyarakat)*, vol. 3, no. 2, 2019, doi: 10.30595/jppm.v3i2.4460.

[5] R. Kartasudjana, "Penetasan Telur," *Modul Progr. Keahlian Budid. Ternak*, pp. 1–43, 2001.

[6] M. Fajri, H. Amnur, and A. Erianda, "Alat Pengatur Suhu pada Mesin Penetas Telur Ayam menggunakan Mikrokontroler, Android dan Server AWS (Amazon Web Service)," *JITSI J. Ilm. Teknol. Sist. Inf.*, vol. 1, no. 3, 2020, doi: 10.30630/jitsi.1.3.16.

[7] A. A. R. Sentono, "Rancang Bangun Inkubator Penetas Telur Berbasis Internet Of Things," pp. 1–29, 2020.

[8] A. R. Mahmud, "Pembuatan Mesin Penetas Telur Otomatis Berbasis Mikrokontroler," pp. 1–96, 2021.

[9] E. Fadhila and H. H. Rachmat, "Pengendalian Suhu Berbasis Mikrokontroler Pada Ruang Penetas Telur," *J. Reka Elkomika ©Teknik Elektro | Itenas |*, vol. 2, no. 4, pp. 2337–439, 2014.

[10] S. Ridho, *ALAT PENETAS TELUR OTOMATIS BERBASIS MIKROKONTROLER*, vol. 561, no. 3. 2019.

[11] P. Simbolon, "Rancang Bangun Mesin Penetas Telur Otomatis." 2016.

[12] A. Wanto, "Analisis Penerapan Fuzzy Inference System (FIS) dengan Metode Mamdani pada Sistem Prediksi Mahasiswa Non Aktif (Studi Kasus: AMIK Tunas Bangsa Pematangsiantar)," *Pros. Semin. Nas. Inov. dan Teknol. Inf.*, no. November 2016, 2016, [Online]. Available: http://j-ptiik.ub.ac.id

[13] M. Rivai, Rendyansyah, and D. Purwanto, "Implementation of fuzzy logic control in robot arm for searching location of gas leak," *2015 Int. Semin. Intell. Technol. Its Appl. ISITIA 2015 - Proceeding*, no. December 2016, pp. 69–74, 2015, doi: 10.1109/ISITIA.2015.7219955.

[14] C. L. Haura, I. Yanti, and M. Pauzan, "Alat Pendeteksi Formalin Menggunakan Deret Sensor HCHO dan MQ-7 dengan Logika Fuzzy," *J. Nas. Tek. Elektro dan Teknol. Inf.*, vol. 12, no. 2, pp. 117–123, 2023, doi: 10.22146/jnteti.v12i2.7097.

[15] L. Qothrunnada, I. Yanti, M. Pauzan, U. Wiralodra, P. Korespondensi, and L. Fuzzy, "IMPLEMENTASI LOGIKA FUZZY PADA ALAT PENDETEKSI KUALITAS MINYAK GORENG BERDASARKAN pH DAN TINGKAT KEJERNIHAN IMPLEMENTATION OF FUZZY LOGIC IN COOKING OIL QUALITY DETECTION DEVICE BASED ON pH AND CLARITY LEVEL," *J. Teknol. Inf. dan ilmu Komput.*, vol. 11, no. 1, 2024, doi: 10.25126/jtiik.20241118289.

[16] A. Patel, S. K. Gupta, Q. Rehman, and M. K. Verma, "Application of Fuzzy Logic in Biomedical Informatics," *J. Emerg. Trends Comput. Inf. Sci.*, vol. 4, no. 1, pp. 57–62, 2013, [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.644.2777&rep=rep1&type=pdf

[17] A. Fathoni, M. Mustain, and R. Wardhani, "Sistem Pendukung Keputusan Penjurusan Siswa Pada Sma Pancamarga 1 Lamongan Menggunakan Metode Fuzzy," *Joutica*, vol. 3, no. 1, p. 151, 2018, doi: 10.30736/jti.v3i1.202.

[18] N. Iksan *et al.*, "Sistem Kendali Suhu dan Kelembapan pada Alat Penetas Telur Berbasis Fuzzy Logic Controller," *JEPIN (Jurnal Edukasi dan Penelit. Inform.*, vol. 8, no. 2, pp. 245–254, 2022.

[19] S. Darmo, I. . Alit, I. . B. Susana, I. . Joniarta, and S. Sultan, "Penetas Telur Sistem Rak Putar Dengan Kontrol Suhu RTD," *J. KARYA Pengabdi.*, vol. 2, no. 1, 2020, doi: 10.29303/jkp.v2i1.37.

[20] F. Rahman, S. Sriwati, N. Nurhayati, and L. Suryani, "RANCANG BANGUN SISTEM MONITORING DAN KONTROL SUHU PADA MESIN PENETAS TELUR OTOMATIS BERBASIS MIKROKONTROLER ESP8266," *ILTEK J. Teknol.*, vol. 15, no. 01, 2020, doi: 10.47398/iltek.v15i01.499.

[21] F. B. Paimin, *Membuat dan Mengelola Mesin Tetas*. 2011.

[22] R. Hidayah, I. Ambarsari, and S. Subiharta, "Kajian Sifat Nutrisi, Fisik dan Sensori Daging Ayam KUB di Jawa Tengah," *J. Peternak. Indones. (Indonesian J. Anim. Sci.*, vol. 21, no. 2, p. 93, 2019, doi: 10.25077/jpi.21.2.93-101.2019.

[23] S. Rahadi, "Buku Manajemen Peternakan Ayam Petelur." pp. 33–34, 2012.